AVAIL

Arctic Vulnerability To Radioactive Contamination

FIRST TWELVE MONTH PROGRESS REPORT
FOR THE PERIOD 1.9. 1998 - 31.8. 1999

Edited by

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Norwegian Radiation Protection Authority

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FIRST YEAR PROGRESS REPORT
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Table of content

1. Management progress report

1.1 Organisation of the collaboration

NRPA co-ordinates the project, and is also co-ordinating work package 2 and 3. The co-ordination of the remaining work pages is as following: HYD/RCMA co-ordinate work package 1, IRH co-ordinates work package 4 and ITE co-ordinate work package 5. The Institute of Terrestrial Ecology, ITE, has become the to Centre for Ecology and Hydrology (CEH). From now on CEH will be used as abbreviation for the project partner. The structure of the projects and the linkage between the work packages, as given in the projects technical annex is shown in Figure 1. Collaboration between the partners has been achieved according to the technical annex.

Project structure

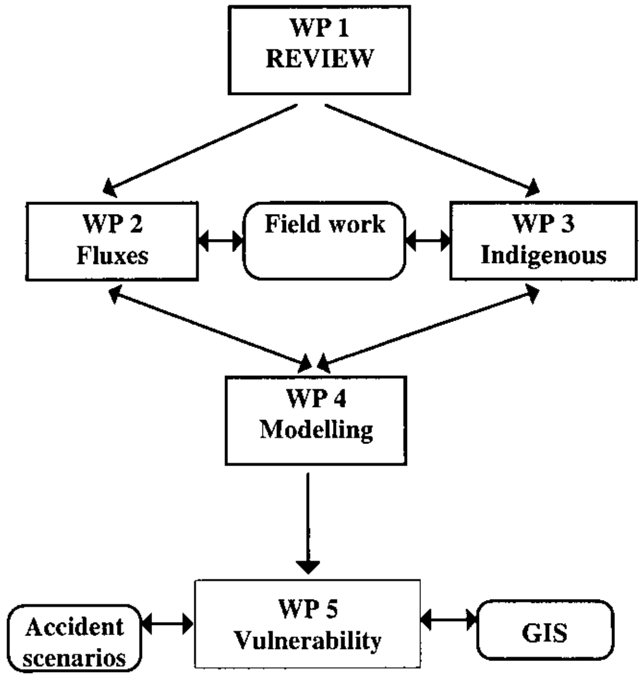


Figure 1 : Flowchart showing inter-linkages between work packages

1.2 Meetings

During the first year of the project one full contractor meeting has been held. However, project participants have met other occasions, under different auspices.

1.3 Exchanges

In March 1999, Irina Travnikova from RTCP/IRH visited NRPA and attended the regular whole body measurement and diet interviews of the Norwegian Sami population living in the areas affected by the Chernobyl accident. A visit of Dr. V. Golikov from IRH to NRPA, 7-11 June 1999 was a part of the work in WP4 considering testing and development of the model: Reindeer-Lichen-Man using the AMAP database.

1.4 Problems encountered

No management, administrative or financial problems are reported during the first year of the project. There has been a delay in the digital processing of geographical maps of the Arctic, however, this delay did not influence the progress of the project.

2. Scientific progress report

The overall aim of AVAIL is to assess the transfer of radionuclides through food-chains delivering fluxes to man or biota, based on the concept of *vulnerability*. The vulnerability of an area is governed by factors such as types of food production, peoples' diet and the management of the land and aquatic environment. Vulnerable areas can be defined using different criteria, e.g. high transfer to foodstuffs (e.g. certain mushroom species in semi-natural ecosystem), high production of foodstuffs which accumulate radionuclides to a large degree and areas that are exposed to high rainfall that may cause high deposition. The use of food processing that leads to the concentration of contamination and dietary preferences which lead to the ingestion of more contaminated foodstuffs, will also contribute to the definition of vulnerability. The concept of vulnerability will be developed as part of this project and used as a tool to compare different Arctic areas by means of a vulnerability index.

Preliminary studies shows that, in terms of transfer of radionuclides to man, Arctic ecosystem (especially the terrestrial component) is much more vulnerable to fallout than ecosystems in more temperate areas. This are due to high transfer rates in the Arctic environment, the extensive use of semi-natural ecosystems for foodstuffs and local dietary habits. This is especially true for indigenous peoples in Arctic Russia.

Programmes for monitoring the radionuclide content of different environmental media have been undertaken in certain areas in the Arctic since the 1960's, and provide results of varying completeness. These monitoring programmes provide information vital in any consideration of an accidental nuclear release and allows an assessment of environmental contamination arising from past releases and present routine releases. Such data includes the radionuclide content of environmental samples, local food products and humans, and can be used to quantify the environmental transfer of radionuclides.

Results can be used to assess potential internal and external doses to man, and to evaluate the consequences of radioactive contamination of northern environments for man and biota.

2.1 Synthesis and evaluation of currently available information, WP1

The overall aim of this work package is collate and synthesise currently available information. This collation is necessary to get a overview of existing data and see if they can be utilised as input into assessment models, describing the transfer of radiocaesium and radiostrontium via the different exposure pathways. The valuation is necessary to identify gaps of knowledge so that effort in the other work packages can be focused appropriately.

2.1.1 Objectives and planned actions

According to the projects planned actions for work package 1 most of the work should be done within the first year of the project. Through an extensive collaboration with several Russian institutes, a large amount of relevant data from historical monitoring programmes in Russia has been collated within AMAP, the Arctic Monitoring and Assessment Programme. The overall aim of the project is to identify vulnerable areas for radioactive contamination in the Arctic. Geographical Information System, GIS, is a tool for modelling vulnerability and to analysed and displayed vulnerability spatially. This means that much work has been performed to digitalise background information as soil maps, topographic maps, vegetation map, landuse and current deposition maps.

- *Review of contamination in the Arctic.* The rational behind this part of the work package was to digitalise the currently available information on the contamination situation in the Arctic and to identify the sources of contamination.
- *Review of transfer/fluxes in the Arctic.* The rational behind this work is to identify concentration and fluxes of radionuclides in different food products that are important in the food chain in the Arctic. This information is necessary to make impact assessment for future contamination in the Arctic and to understand the present situation of exposure to man in this area.
- *Collation of dietary information.* Information of dietary intake is important to the identification of critical groups for radioactive contamination and to perform dose assessments.
- *Collation of demographic information.* Demographic information is an important parameter in the dose assessment for external exposure and also to quantify populations groups with different habits.
- *Collation of habit survey data* Information on habits is important to identify critical groups.
- *Identification of knowledge gaps.* The use of Geographical Information System, GIS, requires digitised information of spatial varying information. Work must be performed to make digitalisation of background information such as soil maps, vegetation maps and landuse maps.

2.1.2 Contribution from individual partners

The WP1, Synthesis and evaluation of currently available information, is co-ordinated by HYD/RCMA with input from NRPA, IRH. and CEH

Review of contamination in the Arctic

The review of contamination of the Arctic is based on information arising from AMAP Phase 1 which largely considered data presented in the annual official reviews of Roshydromet: «Radiation Situation in the Arctic area» and «Russian Federation Environment Contamination». An improved version has been prepared in a report called: «Review of Radioactive Contamination of European Part of Russian Arctic» (HYD/RCMA). Some of the data are presented in Figure 1 and a detailed digitised deposition maps from Kola peninsula has been made for this project at a in scale of 1: 500 000, shown in Appendix I.

Deposition estimates from the atmospheric nuclear weapon tests have been performed and the deposition map of a larger region of the Russian Arctic has been modelled by integrating precipitated ^{137}Cs (CEH) as shown in Figure 2.

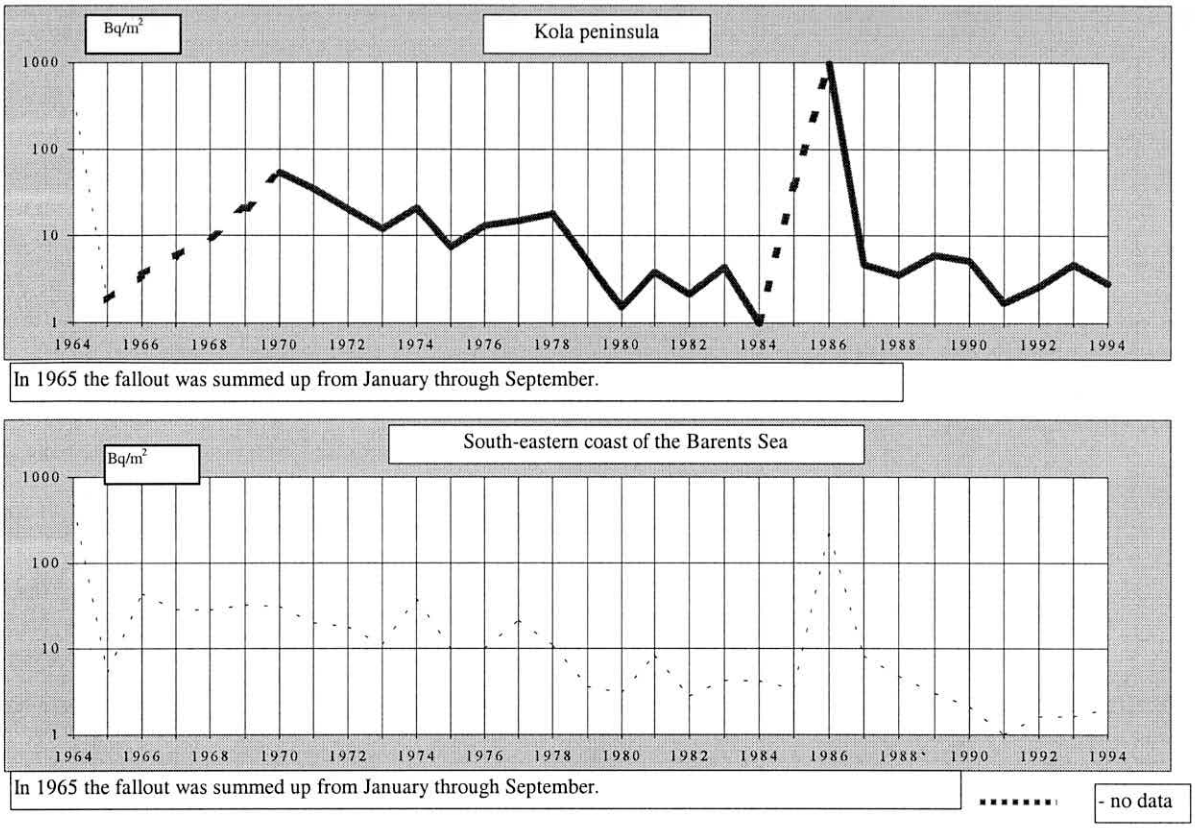


Figure 1. Total annual atmospheric fallout of ^{137}Cs, 1961-1994 (adopted from Tsaturov et al., 1997).

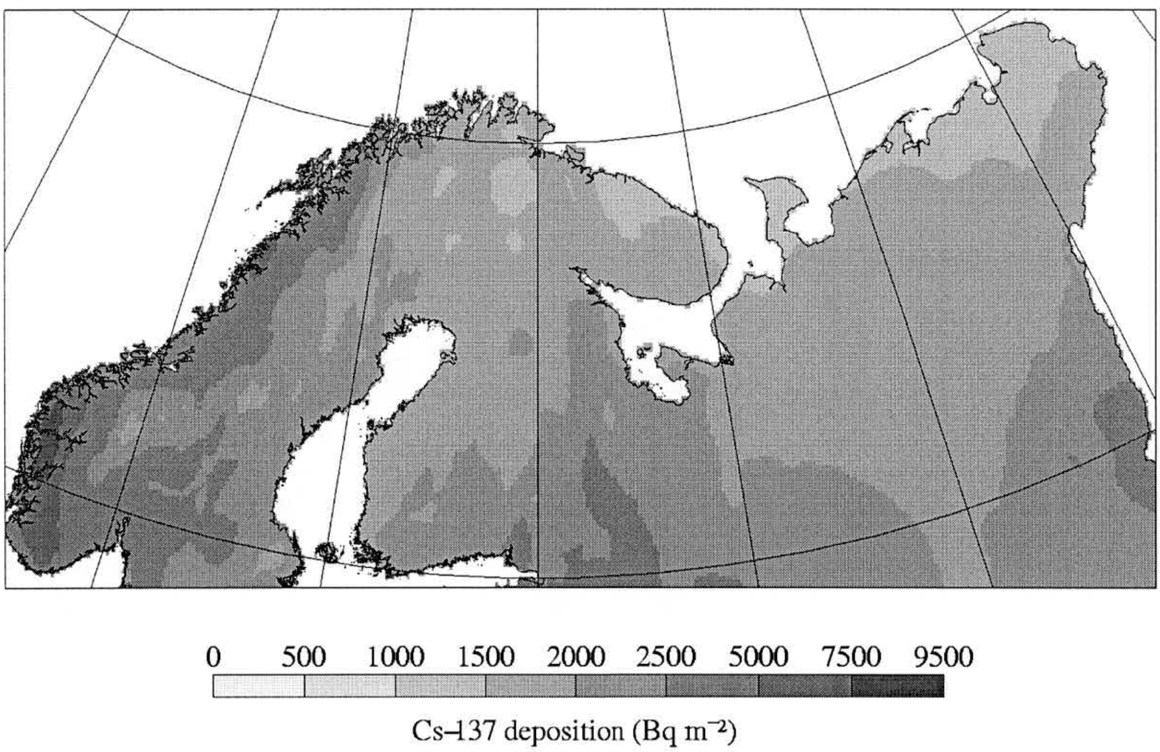


Figure 2. Estimated ^{137}Cs ground deposition in Arctic Norway and north west Russia, and adjoining countries, in 1965

Collation of demographic information

Available official demographic information on the Russian Arctic areas, within the geographical boundaries of the project have been collated. The geographical borders are shown in Figure 6 in the partner progress report from HYD/RCMA. Available demographic statistical information on territories of Murmansk county, Nenets Autonomous Region and Mezen district of Arkangelsk county is being collected and digitised. Information on Murmansk county is completely summarised and currently it is mapping for preparation of the digital thematic layers in the system GIS, Map Info.

The information on other territories will be digitised in the second year of the project.

Review of transfer/fluxes in the Arctic

Aggregated transfer coefficients need to be treated as time dependent factors and by dividing into short term and long term Tags. Different foodstuff will contribute differently to the flux dependent on the relevant time elapsed since deposition, Table 1 (CEH, NRPA).

Table 1. Assumed intervention limit, initial Tag, short-term critical load and long-term Tag for reindeer and moose meat and cow milk in Arctic Norway and north west Russia.

Product	Intervention limit ($Bq\ kg^{-1}$)	Initial Tag ($m^2\ kg^{-1}$)	Short-term critical load ($Bq\ kg^{-1}$)	Long-term Tag ($m^2\ kg^{-1}$)
Reindeer meat	3000	1.5	2000	0.2
Moose meat	3000	0.02	150000	0.0124
Cow milk	370	0.01	37000	0.0006

The selection of appropriate Tag values is essential to the estimation of critical loads. However, it can be difficult to derive representative Tag values due to the lack and quality of available data. In the example above, single Tag values for each product were estimated by integrating measured ^{137}Cs activity concentrations from the AMAP database with predicted ^{137}Cs ground deposition from global fallout, or, in the case of moose meat, from a literature survey. The variation in the transfer of radionuclides can be partially explained by environmental factors such as soil type and land management practices. If spatial data of sufficient resolution and quality can be obtained, the spatial variation in ^{137}Cs critical load could be quantified. Furthermore, more mechanistic approaches for the modelling of the spatial variation in the transfer of radionuclides (e.g. Howard *et al.* 1999) could be adopted if data on the spatial variation in soil properties affecting the transfer of radionuclides are available.

The first phase of the Arctic Monitoring and Assessment Programme (AMAP 1998) concluded that terrestrial and freshwater Arctic ecosystems are particularly vulnerable to radioactive contamination. It also estimated that doses to indigenous population groups from global fallout arising from atmospheric nuclear weapons tests were much higher than to population groups in temperate latitudes. Vulnerability to radiocaesium deposition in Arctic environments was due to the high transfer of radiocaesium to certain terrestrial and freshwater semi-natural foodstuffs and the importance of these foodstuffs in the diet of indigenous population groups.

Collation of dietary information and collation of habit survey data

Dietary information and habit survey data relevant to indigenous people of the Russian Arctic (European part) are being collated from the published literature. Reindeer herders from Lovozero in the Murmansk region have been whole body monitored in 1991-1992 and 1995 by Miretskly *et. al* (1993) and Rahola, (1995). This settlement has been followed up in this project by work package 3 so that additional information has been collected during field works in the Kola region (1998-1999) and Arkangelsk region (1999). This survey included social and demographic data, description of dwelling type, relevant natural and climate data. Personal interviewing of inhabitants was performed according to a special questionnaire see (Appendix 2).

Rates of internal and total exposure to population varies with lifestyle, dietary habits and place of residence. Consumption of local natural food products provides the principle contribution to human internal exposure.

It has been shown that consumption of local reindeer meat, freshwater fish and mushrooms leads to increased internal and total exposure of inhabitants of the European part of the Russian Arctic. Where a local populations diet contains significantly amounts of these food products, this population group will be exposed to a higher risk. Inhabitants of large Arctic cities are exposed to less risk because their diet is based on imported food. Their risk level is comparable to that of temperate latitudes.

Identification of knowledge gaps

Knowledge gaps were discussed and identified during the first project meeting in St. Petersburg, December 1998. (see minutes Appendix 3), and the required digitalisation of spatially variable information was identified. The digitised map contains tables of object characteristics to make it possible to create thematic maps related to radioecological features. The maps that are digitised are discussed below, (HYD/RMCA)

Soil, topographic and discussed vegetation cover information for Murmansk county is fully digitised and prepared for incorporation into a digital map. Information on agricultural use of land and on reindeer pastures areas in Murmansk county and (NAR) has also been collected and digitised. Information on Murmansk county is also prepared in form of digital electronic maps of scale 1:1,000,000 and 1:500,000.

Based on official topographic maps at a scale of 1:500,000 a digital map of Kola peninsula is being prepared in the form of layers according to types of topographic information, including:, coastline of the sea, land, adjacent part of the sea, geographical names, terrestrial water objects (lakes, rivers), swamps, elements of the landscape , areas of woods and bushes and settlements.

Information on the condition of soil and vegetation cover in the Kola peninsula and Nenets Autonomous Region is collected and digitised. Information on the Kola peninsula has been prepared in the form of digital electronic maps at a of scale of 1:500000, using as topographic base of layers of digital topographic map containing coastline, terrestrial water objects. A Full list of maps which were prepared in 1999 is presented in Appendix I.

In 2000 (second project year) we plan to fully complete digital mapping of information on the Nenets autonomous region and Mezen district of Arkangelsk county, and also to prepare digital map information on the thickness of snow cover and amount of precipitation in this area.

The digitalisation of maps will allow other participants of the project (NRPA, IRH, CEH) to use the information in operative dose models in the Arctic for all territories included in the project.

There is little knowledge of dietary and habits of the Indigenous people living in the Nenets region of Arctic Russia. Contacts has been established in that region to make a similar survey of dietary and habits as for settlements at Kola peninsula.

Important information has been collated on contamination of fresh water fish under separate project (bilateral Russian - Norwegian collaboration). Dr. I.Kryshev from "Typhoon", Obninsk, is developing a model for a fresh water ecosystem within the framework of the bilateral project. This data will be incorporated into the Flux work package, WP 2.

2.1.3 Problems Encountered

None in the reporting period

2.1.4 Publications and papers

A report made by HYD/RCMA «Review of Radioactive Contamination of European Part of Russian Arctic» A technical deliverable on contamination in the Arctic will be finished January 2000. Publication is expected during 2000.

2.2 Fluxes in the Arctic environment, WP 2

The main objectives of the work package is to quantify factors influencing differences in contamination of food products, so that geographical variation in transfer can be modelled, and to identify those areas with the greatest potential net output of radionuclides in different foodstuffs.

2.2.1 Objectives and planned actions

The quantification of fluxes has been achieved through field studies and the use of relevant transfer and production data. This data will be used to parametrise internal dose models. The field work involves sampling of vegetation and soils covering a wide range of ecosystems. Special emphasis is being placed on wild foods (mushrooms, berries and game animals) and those foodstuffs consumed by indigenous peoples.

- *Sampling strategy.* The sampling strategy is being defined so that the data can be comparable between surveyed regions. This sampling strategy is necessary to be sure that the collation of data can be used in planned assessments.
- *Field-work - soils, foodstuffs.* Natural food products are important pathways for exposure to man. Some of these products have received little analytical attention to determine activity concentration or to estimate transfer in the past. Mushrooms and berries are of special concern, due to known to high transfer of radiocaesium.

2.2.2 Contribution from individual partners

The WP2, Fluxes in the Arctic environment, is co-ordinated by NRPA with input from HYD/RCMA, IRH and CEH

Sampling strategy

During the first meeting in St. Petersburg, the sampling strategy was agreed upon based on geographical areas. Soil, food and vegetation samples would be collected together with knowledge of location. This is necessary according to the main goal of this project to survey spatially varying factors that are important to identify vulnerable areas. Food products that are grown or gathered in Arctic ecosystems and vegetation (e.g. lichens) that are grazed by animals would be sampled and measured.

Field-work - soils, foodstuffs.

During the field work in the late summer of 1999 three villages in Mezen district in Arkangelsk region were visited where populations were involved in reindeer breeding. In addition to the interviews and whole body counting of ^{137}Cs from selected people from the villages, samples of traditional gathered foodstuff and soil samples were measured for ^{137}Cs. Soil samples as well as 6 grass mixture samples, 10 lichen and 10 mosses samples, 33 mushroom samples of 10 species and 8 samples of wild berries of 3 species were collected in 4 plots located by GPS. Samples of reindeer meat, lamb meat, beef, cow milk, goat milk, locally produced vegetables and fish of 6 species were purchased from local inhabitants. Data on natural and climatic conditions, vegetation, demographic and production data were collected from local institutions.

In 1998-1999 two expeditions took place to the Kola peninsula, Murmansk region of Russia. The purpose of these fieldwork was to measure present levels of environmental contamination with the long-lived radionuclides, ^{137}Cs and ^{90}Sr, in the north-west of Russia, and thus to assess current internal exposure levels in different population groups of this region.

Transfer factor (TF) equal to the ratio of radionuclide specific activity concentration in dry samples of lichen, mosses, grasses and fungi or fresh samples of other foodstuffs to the surface activity in soil. «σ» is used to characterize migration of caesium and strontium radionuclides from soil into forest products and agricultural foodstuffs. The TFs of ^{137}Cs is calculated for mushroom in fresh weight only to illustrate the dynamic concentration given in Figure 3 and in the internal dose calculation. Aggregated transfer coefficients (Tag) is defined as the ratio of radionuclide activity concentration in animal products (e.g. meat) to the surface activity in soil, which are basically the same as TF. Since animals do not eat the contaminants from soil directly the transfer is called aggregated, caused by grazing of different vegetation.

About 800 analyses of environmental samples and food products are now available from the Kola peninsula. About 300 analyses are from samples taken in 1998-1999 which include 35 gamma-spectrometric analyses of layers of soil profiles, 84 agrochemical analyses of soil samples, about 80 gamma-spectrometric and radiochemical analyses of samples of vegetation (lichens, mosses, grasses, mushrooms and berries, potatoes) and over 70 samples of animal products (milk, reindeer meat, fish). More than 400 gamma-spectrometric and radiochemical analyses for content of ^{137}Cs and ^{90}Sr in vegetable and food products were performed in 1987 - 1997 by specialists of the Murmansk Regional Centre for Sanitary Inspection, (RCSI).

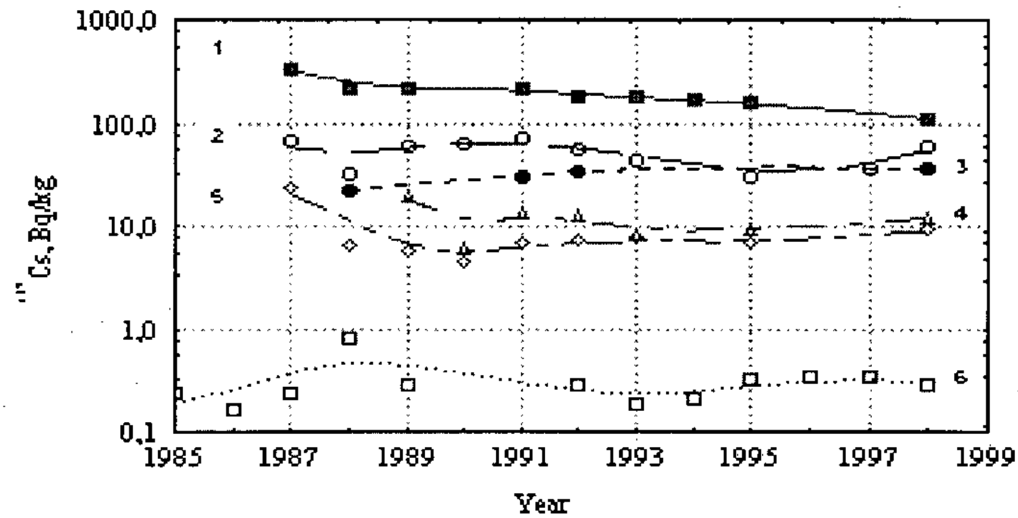


Figure 3. Changes with in ^{137}Cs mean activity concentration in reindeer meat (1), mushrooms (2), cloud-berries (3), bilberries (4), cowberries (5) and milk (6) collected in the Murmansk region.

2.2.3 Problems Encountered

None in the reporting period

2.2.4 Publications and papers

Shutov V.N., Bruk G.Ya., Travnikova I.G., Balonov M.I., Kaduka M.V., Basalaeva L.N., Skuterud L., Mehli H. and Strand P. (1999) The Current Radioactive Contamination of the Environment and Foodstuffs in the Kola Region of Russia. In: Environmental Radioactivity in the Arctic. Ed. by Per Strand and Torun Jølle, NRPA, Østerås, pp. 307-309.

2.3 Indigenous peoples -dietary habits and vulnerability, WP3

The lifestyle of indigenous and other Arctic peoples are closely linked to local resources that provide nourishing food and spiritual connections to the environment. This means that these populations are highly sensitive to local levels of contamination in contrast to populations from more southerly latitudes who often receive foodstuffs from a wide geographical areas. The available data gives inadequate information on the ingestion rates of these foodstuffs, and therefore needs to be improved by obtaining data from specific areas, which may have different environmental and population characteristics.

2.3.1 Objectives and planned actions

The overall objective is to improve dose and risk assessments for both average residents and members of the most exposed populations groups. Collected data will be essential information for parametrisation of dose and vulnerability models. The two parts of the work package started the first year of the project. The fieldwork part started earlier than scheduled in the technical annex.

- *Sampling strategy - Questionnaire preparation.* Develop a questionnaire suitable for investigating Arctic diet and habit situation in urban and rural settlements
- *Fieldwork -Data on diet and habit* The fieldwork yields valuable data for obtaining or improving the different parameters in the dose assessment. The whole body measurements are part of this work to verify the dose models. The other part consists of completing the

questionnaires by Arctic inhabitants, results are used in the study of diets and habits. The surveys are carried out at the same time and by the same people that took part in the whole body measurements as performed in 1998 and 1999.

2.3.2 Contribution from individual partners

The WP3, Indigenous peoples -dietary habits and vulnerability, is co-ordinated by NRPA with input from HYD/RCMA, IRH and CEH.

At the end of June 1999, M. Balonov and I. Travnikova made a preliminary visit to Arkangelsk and agreed with local authorities on the fieldwork for 1999 and 2000 with the participation of foreign partners. The expedition in the Arkangelsk region, Mezen district, located on the Northwest coast of the White Sea was undertaken in August 1999, (IRH V. Shutov, G. Bruk and I. Travnikova).

Three villages were visited during the field work, where the population is involved in reindeer breeding. Seventy-five people were interviewed on their food habits using a questionnaire and eighty-five people were measured for ^{137}Cs content in the body. Vegetation, demographic and production data were collected from local institutions.

As a part of assessment of internal exposure from ^{137}Cs and ^{90}Sr in reindeer herders and the general population there has been two expeditions to the Kola peninsula, Murmansk region of Russia 1998-1999. The immediate purpose of these field works was to assess present levels of environmental contamination with long-lived radionuclides ^{137}Cs and ^{90}Sr in the north-west of Russia, and thus to assess current internal exposure levels in different population groups of this region. The Lovozero settlement in the middle of Kola peninsula, with its indigenous (reindeer herders) and Slavic population was chosen as the main study site in late summer, 1998, and in late winter, 1999, and another settlement Umba with its Slavic population located at the Southern coast of the Kola peninsula was selected in late summer, 1998, as an additional comparative site without an influence of reindeer breeding on human internal exposure. The results of the surveys and measurements show seasonal variations in both diet and the effect on internal dose. The dose was measured to be in Lovozero 19 μSv in the winter versus 10 in the summer. In addition, results show the variations between the different population groups. The reindeer herders had 2,5 up to 3 times higher ^{137}Cs levels than the general (town) population. Of the latter group, not less than 22 out of 25 persons had levels that were lower than the detection limit of the NaI-detector. Finally, the diet assessed dose is in good agreement with the measured dose.

2.3.3 Encountered problems

None in the reported period except that NRPA could not to attend to the field work at the reindeer herder camp 50 km outside Lovozero in late winter 1999. This was due to a delay caused by special weather conditions.

2.3.4 Publications and papers

Travnikova I.G., Bruk G.Ya., Balonov M.I., Shutov V.N., Skuterud L. and Strand P. (1999) Assessment of Current Exposure Levels in Different Population Groups of the Far North. In: Environmental Radioactivity in the Arctic. Ed. by Per Strand and Torun Jølle, pp. 289-291, NRPA, Østerås,

The questionnaire used in the field work in the diet and habit investigation, see Appendix 2.

Collected samples are being analysed and databases as well as expedition report are in preparation. The report is expected to be prepared in winter 2000.

2.4 Modelling of internal and external dose, WP4

In the framework of the present project the main purpose of the modelling was the development of a time dependent and spatially variable biophysical model to calculate internal and external doses from radioactive contamination of Arctic environments by radiocaesium (^{134}Cs and ^{137}Cs) and radiostrontium (^{90}Sr).

2.4.1 Objectives and planned actions

The key elements in an Arctic model should be the incorporation of relevant pathways of important radionuclides. They should include the important 'lichen-reindeer-man' chain for the terrestrial ecosystem, food chains in the freshwater ecosystem, forest ecosystems with regard to mushrooms and berries, and food derived from local agricultural ecosystems. For external dose, relevant information is needed on occupational behavior and the local agricultural practice. The model should have a unified structure for different Arctic regions and take into account regional and social differences in agriculture, dietary habits and use of forest and freshwater environments. It should therefore be supplied with sets of national and regional site-specific parameters relevant to both internal and external exposure of man. The following parts of the work package have been accomplished in the project's first year.

- *Internal dose parametrisation.* The internal dose model is a deterministic model that must be supplied with parameters such as rates of radiocaesium transfer between the different entities represented by arrows in the flowchart given in Figure 4.
- *External dose model application.* For the external dose calculations, use will be made of models that are adapted especially to the Arctic environmental conditions. For example the effect of snow cover will be incorporated.

2.4.2 Contribution from Individual partners

The WP4, Modelling of internal and external dose, is co-ordinated by IRH with input from HYD/RCMA, NRPA and CEH

Internal dose parametrisation

A flowchart of the model is shown in Figure 4. The input data are the local time-integrated the activity concentration in air, the radionuclide activity deposited during precipitation, and the amount of rainfall during rainfall event. These data can be measured by environmental monitoring systems, or predicted with atmospheric dispersion and deposition models. The model include relevant northern food chains: the most important terrestrial lichen-reindeer-man chain, local agricultural chain (in the present version - only cow milk and beef), freshwater chain, and forest chain with mushrooms and berries. For the ingestion pathway, all relevant transfer processes between soil, plants, and animals, such as interception, translocation, root uptake, animal feeding are considered. The output results are time-dependent and time-integrated internal doses, and activity concentrations in plants and animal food products up to 70 y after deposition. Doses are estimated for three groups of population: reindeer-breeders and their families; inhabitants of large industrial cities and rural inhabitants of villages and small settlements who are not involved in reindeer breeding. Corresponding consumption rates and dose factors are applied to calculate the lifetime doses of these groups.

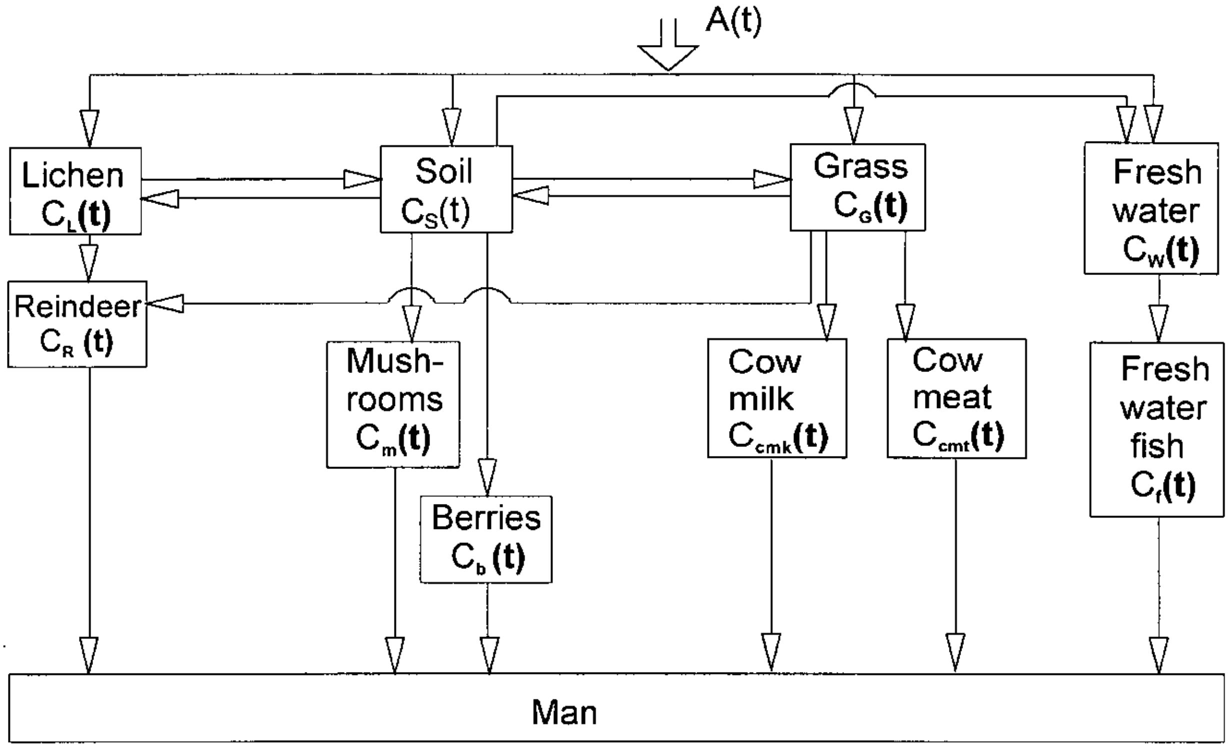


Figure 4. Flowchart of the exposure pathways considered in the model of internal exposure

The above mentioned approach and its computational model with set of equations and default parameters values has been implemented as a computer program. The program was written using the Object-Oriented language (Borland Delphi3). The program has a context dependent help, standard friendly interface for work with many overlapped windows accessed by using mouse and keyboard. With the purpose of an estimation of parameters for the most important terrestrial lichen-reindeer-man chain the special computer program allows simulation of continuous radioactive depositions as a result of nuclear-weapon tests. A feature of this program is the opportunity to estimate parameters of model by comparison of calculation results with experimental data using the least squares method.

A total of 20 reindeer-breeders were polled in late summer 1998 and 23 reindeer-breeders in late winter 1999. In addition, in late summer 1998, 25 inhabitants were surveyed in the Lovozero settlement that were not involved in reindeer-breeding. In addition, 58 persons living in the settlement of Umba in the South of the Kola peninsula were surveyed.

The data on food ration, its structure and contamination of the main dietary components were used for assessment of the intake of radionuclides and the resulting dose of internal exposure to a person. Calculations were performed according to the formula:

$$E_{int} = 365 * \sum_l (dk_l * I_l), \quad \text{mSv/year,} \qquad (1)$$

In equation 1, dk_l - is the dose factor for ingestion of l-th nuclide in the body of an adult; dk_l is equal to $1.3 \cdot 10^{-5}$ and $2.8 \cdot 10^{-5}$ mSv/Bq for ^{137}Cs and ^{90}Sr, respectively (ICRP, 1993);
I_l - is the daily intake of the l-th nuclide in the body with food, Bq/day;
365 - is the number of days in a year.

Daily intake of radionuclide in the human body is combined from the intake with different food products, components of food ration:

$I_l = \sum_p (C_{lp} * V_{lp} * K_{lp})$, Bq/day, (2)

In equation 2 C_{lp} - concentration of l-th radionuclide in the p-th food product, Bq/kg;,
V_{lp} -daily consumption rate of the p-th product, kg/day,
K_{lp} - culinary factor accounting for the loss of l-th radionuclide during cooking of the p-th food product.

Except for the above-mentioned data sources for parameterising the models, results of field examinations of the environmental samples (soil, grass, lichen, mushrooms, berries), data about dietary habits and modes of behaviour of different groups of the population and data about shielding properties of dwellings collected in our recent expeditions will also be used.

External dose model application

As the basic model, we chose the model developed to estimate external exposure to the population living in temperate areas contaminated due to the Chernobyl accident. This model was developed within the project JSP5 - Pathway Analysis and Dose Distributions (EC Report EUR 16541, 1996).

The information necessary for the assessment of the dose in any situation of the external exposure of man includes the following three major categories:

- parameters relating to the external gamma radiation field;
- characteristics relating to the behaviour of man in this field;
- conversion factors relating the gamma radiation field to the dose in the human body.

As a rule, a model for the exposure of man above a grassy virgin plot of soil is used as a base model, and the absorbed dose in air at a height of 1 m above ground $\dot{d}(t)$ as a measure of the radiation field. This field is influenced by several main factors such as the surface activity of deposited radionuclides, their initial penetration, radioactive decay, the process of vertical migration of long-lived radionuclides in the upper soil layer and the presence of snow.

In anthropogenic media, (settlement with its buildings, roads, etc.) the parameters of the radiation field change. In the model, this change is taken into account using location factors f_j. These are defined as the ratio of the dose rate at point j in a settlement (or its vicinity) attributable to the gamma radiation from radioactive deposition to the analogous value above an open virgin soil plot. The behaviour of a man in the field of radiation is described by means of occupancy factors p_{ij}, which are defined by the period of time spent by representatives of the i-th group of the population in the j-th point of a settlement. Finally, the third category of information required for assessment of the dose from external exposure is represented in the model by conversion factors k_i , which relate measurable values such as absorbed dose in air to the human exposure - the effective dose.

This model is intended for the assessment of average organ doses and effective external dose to man in anthropogenic media from the gamma radiation of ^{137}Cs and ^{134}Cs. The basic spatial structure for calculation of the external dose is a separate settlement and its vicinity. Both the dose rate and doses accumulated over an arbitrary time interval (up to the assessment of the lifetime dose) can form outputs. These values may be calculated for a number of population groups. The equations of the model for the rate of the effective dose of external gamma radiation for the representatives of the i-th population group at the time t after deposition of a caesium isotopes is expresses as the follows:

$$\dot{E}_i(t) = \dot{d}(t) \cdot k_i \cdot \sum_j f_j \cdot p_{ij} \quad (1)$$

$$\dot{d}(t) = r(t) \cdot A^{137}\left[g_{137} \cdot \exp(-\lambda^{137} \cdot t) + g_{134} \cdot \frac{A^{134}}{A^{137}} \cdot \exp\left(-\lambda^{134} \cdot t\right)\right] \quad (2)$$

$$r(t) = p_1 \cdot \exp(-\frac{\ln 2}{T_1} \cdot t) + p_2 \cdot \exp(-\frac{\ln 2}{T_2} \cdot t) \quad (3)$$

In equation 2 A^k is the activity deposited per unit area on a reference site (normally lawns or meadows) on the moment of the end of depositions, g_k the gamma dose rate in air per activity per unit area for a initial distribution of the caesium radionuclides in the ground, λ^k the decay constant. The function *r (t)* is the gamma dose rate in air at the reference site divided by the gamma dose rate in air for the initial distribution.

Numerical values for the parameters of the model, for assessment of the external effective dose to the population, were determined on the basis of results of on-site dosimetric investigations after the Chernobyl accident. Some of these parameters, for example, values of conversion factors k_i are rather universal and can directly be used in a given task, others should be defined follow-up, in view of specific behaviour and habitat of the population of Arctic Region, especially reindeer- breeders and their families.

The effective dose of external exposure accumulated during any time interval can be determined by integration of Equation 1, taking into account Equations 2 and 3. The presence of snow cover during winter is not modelled explicitly in Equation (1). Therefore, to account for the influence of a snow cover on the value of annual effective dose of the external exposure integral for a calendar year should be multiplied by a special factor. Its value for different Arctic areas is important parameter of the model.

The basic data source for an estimation of parameters of the model of internal exposure are data from the programs of radiation monitoring performed in the Arctic areas, both after the global fallout and the Chernobyl accident. These data have been collated, through extensive collaboration, in the AMAP data centre at NRPA. The basic difficulties of usage of these data for solving of the problems concerning the present project are:

- incompleteness of the data in space and in time;
- difficulties of the estimation of the model parameters for short-term deposition on the basis of data obtained from continuous deposition;
- a virtually complete lack of data about deposition on snow and subsequent contamination of environmental objects.

2.4.3 Encountered problems

None in the reported period

2.4.4 Publications and papers

The parameterisation of models of an internal and external exposures is planned to be finished in December, 1999, and March, 2000, respectively.

Balonov M., Golikov V., Logacheva I. and Strand P. (1999) Radioecological model of internal exposure of the Man with caesium radionuclides in the Russian and Norwegian Arctic environments. In: Environmental Radioactivity in the Arctic. Ed. by Per Strand and Torun Jølle, pp. 85-87, NRPA, Østerås,.

2.5 Vulnerability and spatial variability, WP5

A primary objective to this work package is develop a means of quantifying vulnerability so that different areas and ecosystems may be compared. At present vulnerability can be assessed during two approaches which will form a useful starting point for this study.

2.5.1 Objectives and planned actions

According to the technical annex this work package was not intended to start in the first year of the project. However, definitions and approaches of quantifying vulnerability have been discussed and are presented. An initial attempt of devising critical load maps for reindeer in the Arctic has been performed using existing data from the AMAP database, interactive and results from WP 1-4. The preliminary results refer to objectives of the work packages below:

- *Definition of vulnerability index* The main objective of a vulnerability index is to enable comparison of different areas in the Arctic. The definition should be in terms of dose to humans.
- *Critical load maps.* The main objective is to identify areas with a high transfer capacity for radionuclides to important food products and to identify problem areas in case of a fallout event.

2.5.2 Contribution from Individual partners

The WP5, Vulnerability and spatial variability, is co-ordinated by CEH with input from HYD/RCMA, NRPA and IRH.

Definition of vulnerability index

One of the main issues here is to define the end point for vulnerability for radioactive contamination. The principle of radiation protection is that if man is protected, the environment is protected. Thus, first approach of defining vulnerability is with reference to man and therefore will refer to a vulnerability index in terms of dose received from a contaminated area. The vulnerability index should enable comparison of areas. The unit that is proposed is Sv per kBq/m^2, possibly integrated over time.

Critical load maps

The critical load approach determines the deposition level that can be present without resulting in food products with activity concentrations above the intervention limit. Critical load maps have been developed for radiocaesium in the European Arctic (see CEH partner report). It has been clearly shown that, especially in the Arctic, previous deposition must be accounted for due to long ecological half-lives. This approach should be extended to consider the different factors controlling variation in transfer from soil to food products.

Further improvements to the application of critical loads to assess vulnerability of Arctic areas to radionuclide deposition currently developed will attempt to account for:

- variation in the production and harvesting of the different food products;
- the time when animals are grazing outside, which will be restricted by the short growing season in the Arctic;
- the use of stored, uncontaminated feed, which will delay the contamination of some food products following any accident; and
- the variation in the growing season, management and slaughtering and hunting/gathering of semi-natural and natural foodstuffs.

- Spatial variation of:
  - soil type and soil properties affecting the transfer of radiocaesium and radiostrontium
  - land cover and land use to allow the identification of areas for the production of different food products
- If sufficient spatial data can be obtained on the above factors they can be included in the assessment and identification of vulnerable areas in Arctic Norway and Northwest Russia

2.5.3 Encountered problems

None in the reported period

2.5.4 Publications and papers

B Howard, S. M. Wright, C.L. Barnett, L. Skuterud, P. Strand (1999). Strand Estimation of critical loads for radiocaesium in the Arctic. In: Environmental Radioactivity in the Arctic. Ed. by Per Strand and Torun Jølle, pp. 85-87, NRPA, Østerås,

3. Partners progress reports

3.1 Norwegian Radiation Protection Authority (NRPA)

3.1.1 Objectives and planned actions

- Review of transfer / fluxes in the Arctic (NRPA / ITE)
- Identification of knowledge gaps (ALL)
- Sampling strategy (NRPA / CEH / IRH)
- Field-work soil, foodstuff (ALL)
- Sampling strategy -questionnaire (NRPA / IRH)
- Internal dose parametrisation (NRPA / IRH/ HYD/RCMA)

3.1.2 Contributions of individual partners

A part of the Work package 1, Synthesis and evaluation currently available information, data from the AMAP database has been used. The review of transfer and fluxes of radionuclides in the Arctic are dependent on sources already collated in the AMAP data base. See the

The AMAP database
In 1994 the ministers of environment in the eight Arctic countries asked for a database on radioactive contamination and actual or potential sources for radioactive contamination in the Arctic areas. This database has been set up as a part of the AMAP data centre for radioactivity at the Norwegian Radiation Protection Authority (NRPA).

When deciding which data to put into the database, a definition of a source and contamination data is needed. In this case, the source is defined as the origin where the radionuclides initially are let into the environment. In some cases a relatively strongly contaminated area may be regarded as a source of radioactivity for a less contaminated neighbouring area (e.g. The Baltic Sea may be considered as a source of radionuclides to the North Sea after the Chernobyl accident) that type of source is not regarded as a source in this database. As the radioactivity already is in the environment, the information should be classified as data on environmental contamination.

The data base had to be constructed as a relational database along two main branches, one holding the contamination data, the other holding the data on sources. The database should be designed to be easily connected to a Geographical Information System (GIS). An existing Sybase server at NRPA was selected as the platform for the AMAP data base, whereas PCs running one or another incarnation of MS-Windows were supposed to be clients to the data base. A Unix based Arc Info GIS and a Windows based version of Arc View GIS are provided with data by the AMAP database.

The contamination part of the database should be able to hold quite inconsistent data sets as it should be used for data collected from a lot of different sample types from all compartment all through the nuclear age. For some of the older data, only averages of several samples are available, whereas for newer data sets, the raw data for each sample together with lots of information on the samples, the sampling, laboratories and analytical procedures are available. The data base should also contain information for quality insurance, such that the confidence on the data could be established.

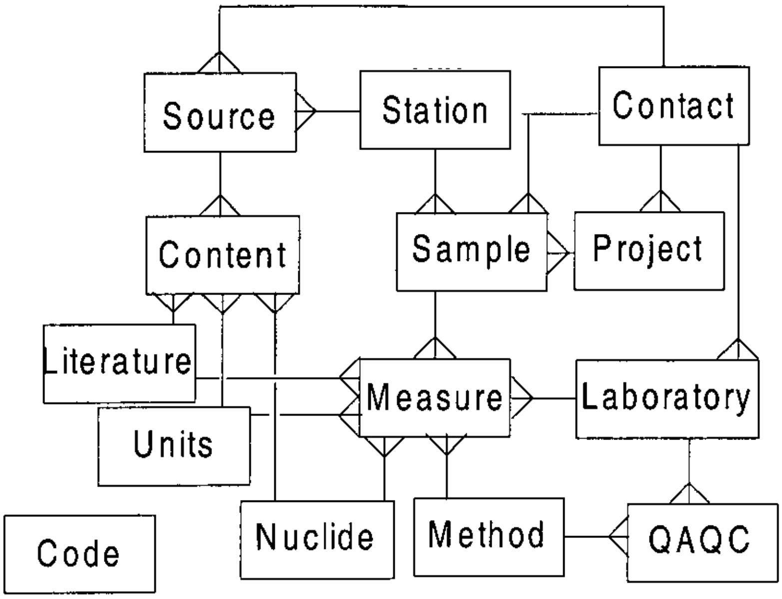


Figure 1 Structure of the AMAP data base for radioactivity. As the Code table has connections to most of the other tables, those connections are not shown to increase readability.

Also the source part of the data base had to be constructed to hold different objects. Some sources have contributed to the existing contamination in the Arctic, but there exist also a lot of objects or installation that may in the future release radioactivity to the environment. Also, some sources have had a one time release (e.g. nuclear weapons tests) other sources have released or are releasing their radioactivity on a longer time span (e.g. reprocessing plants). An overview of the table structure in the data base is given in Figure 1.

The database was taken into use in 1995, after some use, parts of the original design was found to be inappropriate for the actual use of the data base and a revised version was established in 1999.

Field-work soil, foodstuff and Sampling strategy -questionnaire

NRPA attended the field work in Lovozero, Kola peninsula in March 1999 conducted by IRH. The conclusion of the results presented includes contributions from RTCP/IRH and Murmansk RCSI.

Conclusion of two expeditions in 1998 and 1999 to the Kola peninsula, Lovozero, in Murmansk region.

The results of measurement of ^{137}Cs and ^{90}Sr concentration in samples of vegetation and food products collected in 1998 and 1999 showed their satisfactory agreement with the data obtained during the last decade. The analysis of the data obtained during this time period indicates stability of radiation situation on the Kola peninsula. It is a slow decrease of ^{137}Cs content in the main dose-forming food products, mainly due to decay of the radionuclides. Concentration of ^{137}Cs in the reindeer meat decreases with the half-period about 9 years.

The transfer factors for ^{137}Cs and ^{90}Sr from soils of the Kola peninsula to milk, potato, forest berries are close to the TF's of the radionuclides obtained in numerous investigations that was performed in the Bryansk region in the remote time period after the Chernobyl accident (Shutov et al., 1996). This is attributed to similarity of soils of these two regions in their agrochemical properties. Some difference is noted for the ^{137}Cs transfer factors to some mushroom species. This is connected with the greater part of excessively wetted bog soils weakly fixing caesium in Murmansk region as compared with the Bryansk region.

Concentration of ^{137}Cs in lichen, moss and fungi is significantly higher compared with wild higher vegetation (grasses) and agricultural vegetation (potatoes). To lesser extent similar effect can be observed in forest and bog berries growing on soils with low clay content.

Concentration of ^{137}Cs in the reindeer meat consuming lichen in winter and mushrooms in summer is by two orders of magnitude higher than in locally produced beef and pork. It is higher by a factor about 2 in winter when about 80% of reindeer fodder comprises lichen obtained under snow. Concentrations of ^{137}Cs and ^{90}Sr in locally produced cow milk as well as relevant TFs are not higher than these in moderate latitudes.

Relatively high ^{137}Cs concentration in freshwater fish living in Arctic lakes is usually caused by low mineralisation (potassium and other ions) of water. Concentration of ^{137}Cs in marine fish is lower by an order of magnitude compared with freshwater one.

Elevated concentration of ^{137}Cs in some soil samples in the Lovozero district prove its contamination due to the Chernobyl accident, which was earlier found by the Russian State Committee for Hydrometeorology. Another indication of this contamination is increased ^{137}Cs content in mushrooms growing in this district.

Consumption of reindeer meat (about 300 g/day), fish (over 100 g/day), mushrooms (about 20 g/day) and berries (45 g/day) gives the main contribution in the dose of internal exposure of reindeer-breeders. Monthly internal dose in reindeer breeders in late summer 1998 was assessed to be about 10 μSv and in late winter 1999 19 μSv. There is good agreement between internal dose estimations based on intake assessment and whole body measurements.

Inhabitants of the settlement Lovozero not occupied in reindeer-breeding consume reindeer meat by 3.6 times, and meat in general by 2 times less than reindeer-breeders. Nevertheless, in their ration consumption of reindeer meat, fish, mushrooms and berries also gives the main contribution in the dose of internal exposure. Monthly internal dose in this cohort in late summer 1998 was about 4 μSv. Contribution of strontium-90 in the internal dose varies in the range 1 to 5% in different population cohorts.

3.1.3 Publications and papers

- Balonov M., Golikov V., Logacheva I. and Strand P. (1999) Radioecological model of internal exposure of the Man with caesium radionuclides in the Russian and Norwegian Arctic environments. In: Environmental Radioactivity in the Arctic. Ed. by Per Strand and Torun Jølle, NRPA, Østerås, pp. 85-87.
- Travnikova I.G., Bruk G.Ya., Balonov M.I., Shutov V.N., Skuterud L. and Strand P. (1999) Assessment of Current Exposure Levels in Different Population Groups of the Far North. In: Environmental Radioactivity in the Arctic. Ed. by Per Strand and Torun Jølle, NRPA, Østerås, pp. 289-291.
- Shutov V.N., Bruk G.Ya., Travnikova I.G., Balonov M.I., Kaduka M.V., Basalaeva L.N., Skuterud L., Mehli H. and Strand P. (1999) The Current Radioactive Contamination of the Environment and Foodstuffs in the Kola Region of Russia. In: Environmental Radioactivity in the Arctic. Ed. by Per Strand and Torun Jølle, NRPA, Østerås, pp. 307-309.
- B Howard, S. M. Wright, C.L. Barnett, L. Skuterud, P. Strand (1999). Strand Estimation of critical loads for radiocaesium in the Arctic. In: Environmental Radioactivity in the Arctic. Ed. by Per Strand and Torun Jølle, NRPA, Østerås, pp. 85-87.

3.2 Centre for Ecology and Hydrology (CEH)

3.2.1 Objectives and planned actions

- Review of transfer / fluxes in the Arctic (NRPA/CEH)
- Identification of knowledge gaps (ALL)
- Sampling strategy (IRH/NRPA/CEH)
- Field-work soils, foodstuff (ALL)
- Critical load maps (CEH / NRPA / HYD/RCMA)

The first phase of the Arctic Monitoring and Assessment Programme (AMAP 1998) concluded that terrestrial and freshwater Arctic ecosystems are particularly vulnerable to radioactive contamination. It also estimated that doses to indigenous population groups from global fallout arising from atmospheric nuclear weapons tests were much higher than to population groups in temperate latitudes. Vulnerability to radiocaesium deposition in Arctic environments was due to the high transfer of radiocaesium to certain terrestrial and freshwater semi-natural foodstuffs and the importance of these foodstuffs in the diet of indigenous population groups. Furthermore, vulnerability to radiocaesium deposition in the Arctic is highly spatially variable because many of the factors affecting the transfer and fluxes of radiocaesium, such as soil type, agricultural production and land management, and peoples diet, vary geographically. The aim of the AVAIL project is collate all necessary data and develop models for the identification of areas or communities in the European and north west Russian Arctic that are vulnerable to, or conversely, resilient to radiocaesium and radiostrontium deposition. All relevant spatial data is being integrated within a Geographical Information System (GIS). AMAP and the Spatial Analysis of Vulnerable Ecosystems (SAVE) project showed that by accounting for the spatial variability in the transfer of radionuclides in dynamic models it was possible to improve estimates of individual and collective doses for both average and critical population groups (AMAP 1998; Howard *et al.* 1999).

Vulnerability and resilience to radionuclide deposition in the Arctic could be quantified by adopting a *critical loads* approach. The critical loads approach was developed during the 1970s due to concern over the impacts of anthropogenic acidifying emissions on the environment in the Northern Hemisphere. It provides a practical approach for the development and control of emissions strategies at national and international scales. The critical loads approach has been developed to cover a wide range of both pollutants and receptors and can be defined as:
'a quantitative estimate of an exposure to one or more pollutants below which significantly harmful effects on specified sensitive elements of the environment do not occur according to present knowledge' (Nilsson and Grennfelt 1988)

The estimation of a critical load for a pollutant is based upon the dose response behaviour of a receptor to a pollutant – the critical load is set at the level where the pollutant has a negative effect upon a receptor (Figure 1). The approach allows a quantitative estimate of the magnitude of the exceedance of the pollutant over a specified threshold. It is a simple and practical approach, which, because of its transparency, has been adopted by many countries and international organisations for the control of acidifying pollutants.

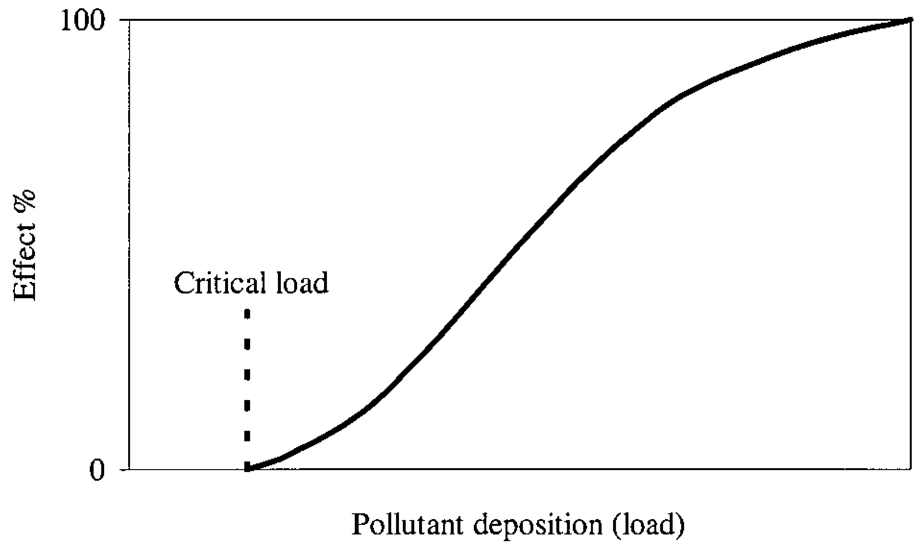


Figure 1. Theoretical dose-response curve and the critical load at which effects can be observed.

Critical load estimation for different pollutants can be set using either equilibrium or dynamic models. Equilibrium models are often related to real biological effects, but may be limited in their application to areas where relevant data have been collected. Conversely, dynamic models may be used to identify the impact of a pollutant upon a receptor over long time scales and allow identification of the rate at which the system will be degraded, which may influence the value of a critical load. Dynamic modelling approaches can be data intensive and may not be practical over large areas.

Once the pollutant dose response for a particular receptor has been quantified, it is possible to attribute critical load values to different geographical areas. It is relatively straightforward to compare the spatial variation in pollutant deposition and critical load to identify those areas where the pollutant exceeds the critical loads and harmful effects will occur. The relationship of pollutant emissions to pollutant deposition provides opportunities for the development of emission controls to prevent exceedances.

Critical loads have been developed for a number of different acidifying pollutants and receptors. Further extensions to the approach have also been developed. *Target loads* can be defined as a critical load that is determined by political agreement, where the threshold is set to represent a balance between environmental and economic costs (Figure 2). The target load can be set higher than the critical load to account for practical, economic or political considerations; if a safety margin is assumed to ensure the critical load is not exceeded, the target load can be set lower than the critical load. Furthermore, *multi-pollutant multi-receptor* approaches have also been developed; for example, it is possible to consider the combined impact of Sulphur and Nitrogen deposition upon the environment when establishing protection criteria (Figure 3).

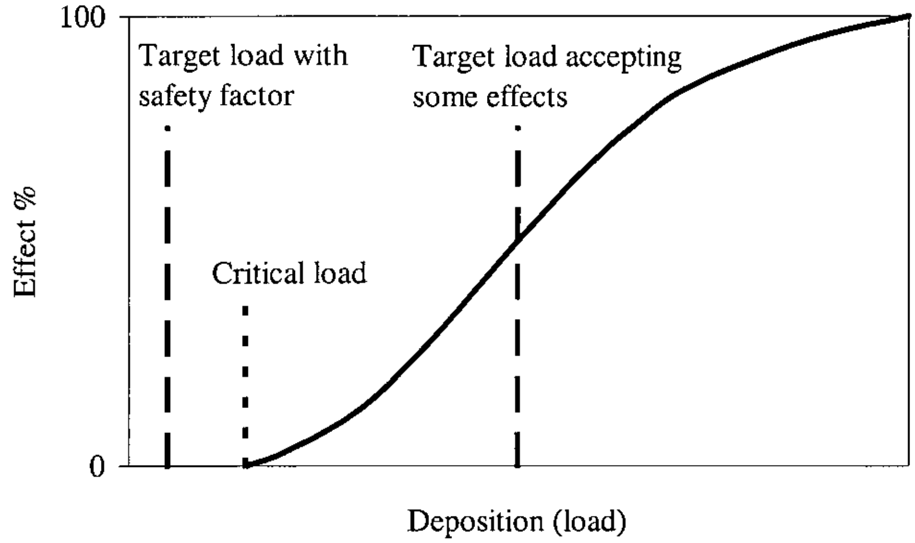


Figure 2. Theoretical dose-response curve showing comparison of target loads with critical load.

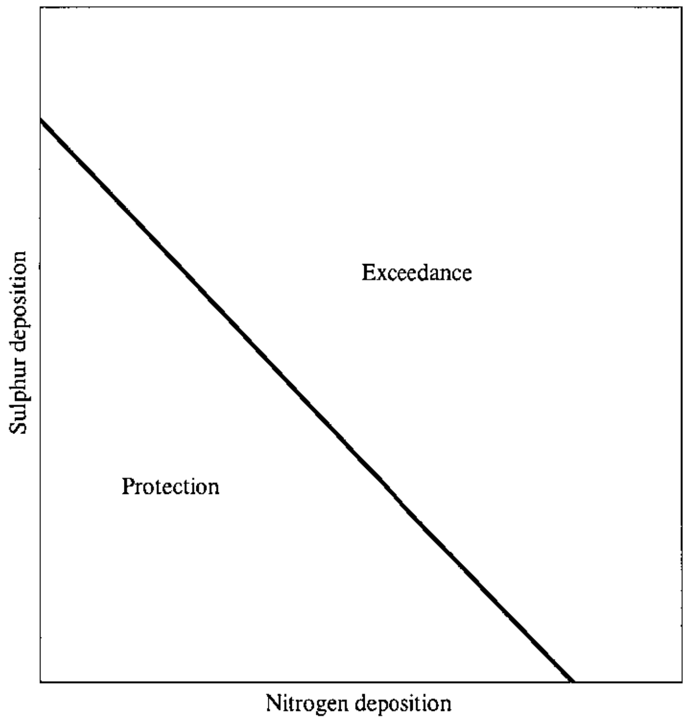


Figure 3. Critical load function for Sulphur and Nitrogen deposition.

In the same way critical loads for acidifying pollutants has become a tool for the management of emissions strategies, critical loads for radioactivity could become a useful and simple tool for the identification of areas that may be vulnerable to radionuclide deposition and improve the management of responses to nuclear accidents. Critical loads for radionuclides can be defined as the amount of radionuclide deposition necessary to produce radionuclide activity concentrations in food products exceeding intervention limits for areas used in the production or harvesting of foodstuffs (Wright *et al.* 1998). Alternative definitions of critical loads for radionuclides could consider radionuclide fluxes (the product of radionuclide activity concentration in a food product and its production from a specified area over a specified time), radionuclide ingestion rates or doses from radionuclides. In the event of a nuclear accident, critical loads for radionuclides could be readily integrated with radionuclide deposition maps to identify those areas where countermeasures may be required.

The soil-plant transfer of radionuclides is often expressed as an aggregated transfer factor (Tag, with units m^2 kg^{-1}) which can be defined as the ratio of the radionuclide activity concentration (Bq kg^{-1}) in a food product to the radionuclide ground deposition (Bq m^{-2}). Tag values are used to model radionuclide transfer to semi-natural food products due to the heterogeneity of natural environments (IAEA 1994) and should only be applied in the period following radionuclide deposition when all directly deposited material has been weathered from plant surfaces. The time dependence of radionuclide soil-plant transfer can be modelled using an ecological half-life – the time taken for the radionuclide activity concentration in the plant to reduce to half of the original. Ecological half-lives for radionuclide soil-plant transfer to semi-natural food products are often very long and approximate to the physical decay of the radionuclide. Therefore, critical loads for radioactivity can be defined as the ratio of the intervention limit for a food product and the Tag value. For example, integrating predicted ^{137}Cs ground deposition (Wright *et al.* 1999; Figure 4) with measured activity concentrations in reindeer meat in Arctic Norway and north west Russia from the AMAP database an initial Tag of 1.5 m^2 kg^{-1} for the period of maximum ^{137}Cs global fallout (1965) can be estimated. Assuming a reindeer meat intervention limit of 3000 Bq kg^{-1}, the ^{137}Cs critical load for reindeer meat would therefore be 2000 Bq m^{-2}. Estimated initial critical load values for other food products in Arctic Norway and north west Russia are shown in Table 1.

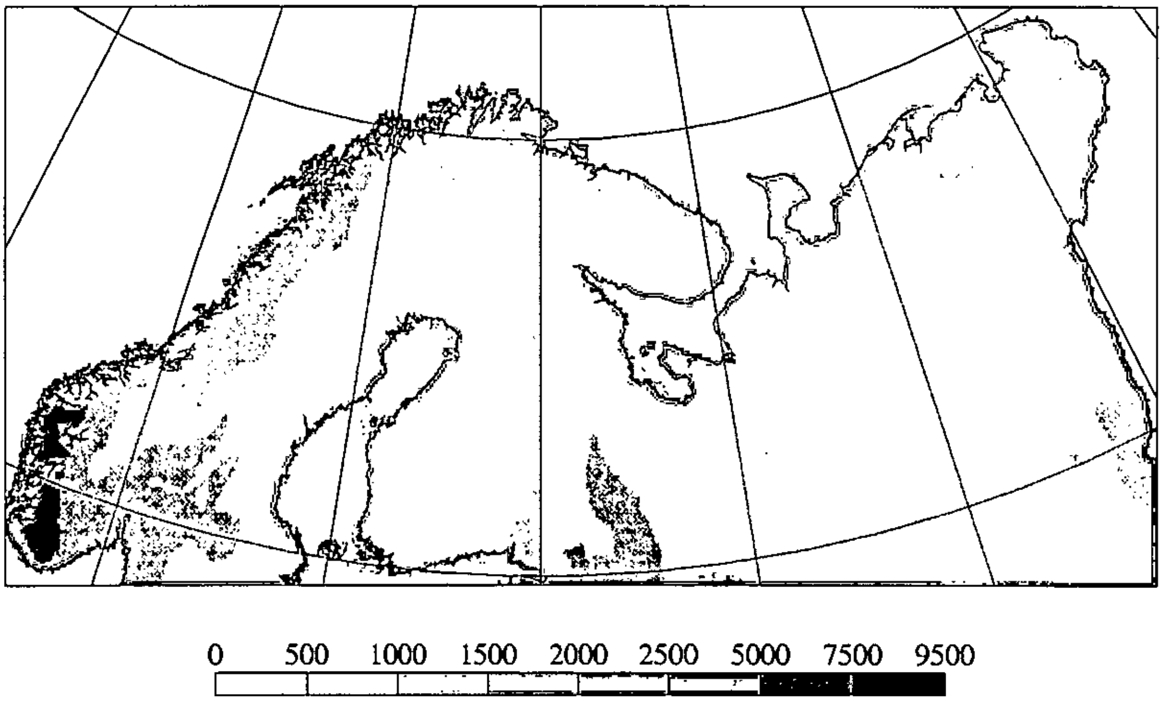


Figure 4. Estimated ^{137}Cs ground deposition in Arctic Norway and north west Russia, and adjoining countries, in 1965.

Table 1. Estimated initial Tag values, intervention limits and critical loads for a range of food products in Arctic Norway and north west Russia.

Product	Tag ($m^2\ kg^{-1}$)	Assumed intervention limit ($Bq\ kg^{-1}$)	Critical load ($Bq\ m^{-2}$)
Cow milk	0.01	370	37000
Sheep meat	0.38	600	1580
Moose meat	0.03	3000	100000
Potato	0.002	600	300000
Edible fungi	0.41	600	1460
Berries	0.16	600	3800

When estimating critical loads for food products from ecosystems with long ecological half-lives it is important to account for both the level and bio-availability of any existing radionuclide deposition. Therefore, to estimate the ^{137}Cs critical load for reindeer meat following the Chernobyl accident account must be made of the existing ^{137}Cs ground deposition from global fallout. A long-term Tag value for reindeer meat of 0.2 $m^2\ kg^{-1}$ derived from data for the period just prior to the Chernobyl accident in 1986 and estimated by integrating the predicted ^{137}Cs ground deposition in 1985 with measured ^{137}Cs activity concentrations in reindeer meat in Arctic Norway and north west Russia. Combining the prediction of ^{137}Cs ground deposition from global fallout prior to the Chernobyl accident with the long-term Tag enables the ^{137}Cs critical load for reindeer meat after the Chernobyl accident to be estimated accounting for existing ^{137}Cs ground deposition (Figure 5). As would be expected, the estimated critical load is smallest where global fallout is greatest. Figure 6 illustrates how such critical load maps could be used in the event of a nuclear accident. The predicted ^{137}Cs ground deposition in 1985 from global fallout has been subtracted from the total ^{137}Cs ground deposition following the Chernobyl accident (De Cort 1998) to estimate the spatial variation in ^{137}Cs ground deposition from the Chernobyl accident. By comparing this to the ^{137}Cs critical load map for reindeer meat in Figure 5 the areas where the Chernobyl ^{137}Cs deposition exceeded the ^{137}Cs critical load for reindeer meat can be identified. Figure 6 has been presented to show areas where the ^{137}Cs critical for reindeer meat has not been exceeded (green); areas of exceedance, quantified as the ^{137}Cs ground deposition above the estimated critical load, are shown in three classes (yellow, orange and red): these could represent where different countermeasure strategies should be applied. Areas with no estimated ^{137}Cs ground deposition from the Chernobyl accident are shown in white. It should be noted that both Figures 5 and 6 should be amended to reflect the distribution of reindeer meat production - it is not relevant to predict ^{137}Cs critical load values or exceedances for where areas where reindeer meat production does not occur.

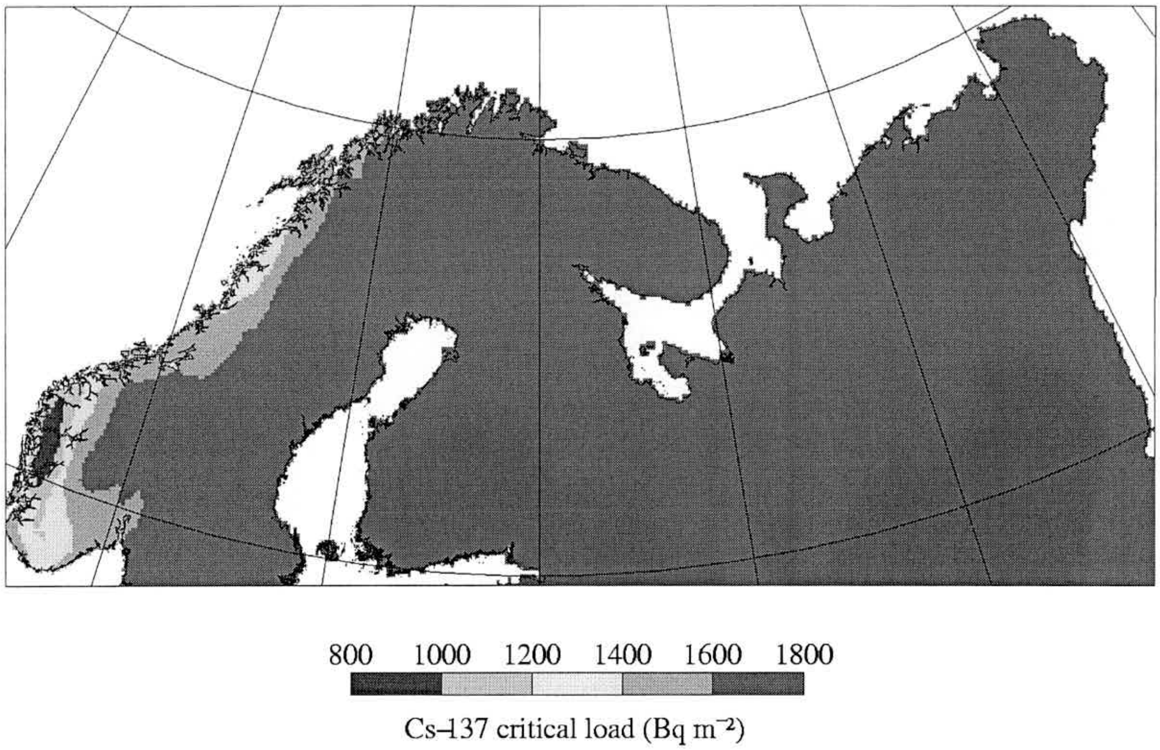


Figure 5. Estimated ^{137}Cs critical load for reindeer meat following the Chernobyl accident accounting for ^{137}Cs ground deposition from global fallout.

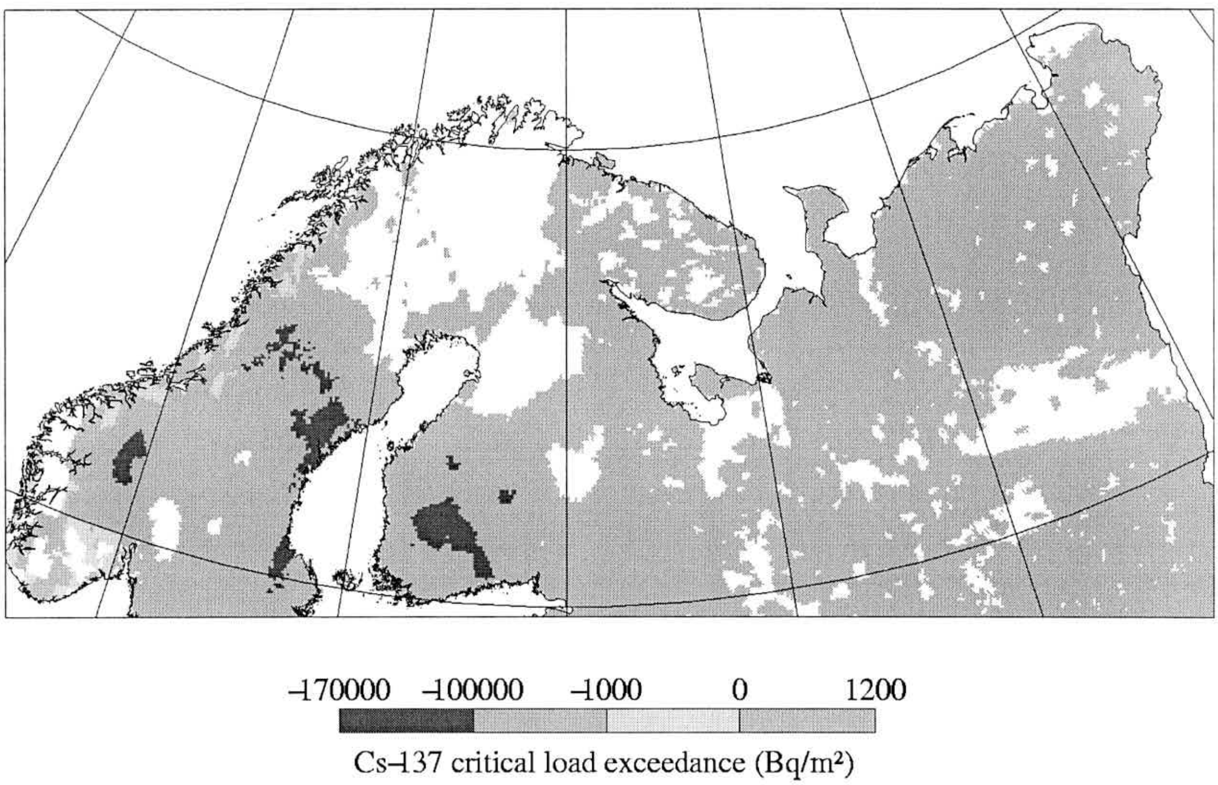


Figure 6. Cs-137 exceedance for reindeer meat following the Chernobyl accident. Negative values indicate areas where estimated Chernobyl ^{137}Cs ground deposition exceeds the predicted ^{137}Cs critical load for reindeer meat following the Chernobyl accident accounting for ^{137}Cs ground deposition from global fallout.

The same approach can be extended to quantify the dependency of the ^{137}Cs critical load on existing ^{137}Cs deposition for different food products in Arctic Norway and north west Russia. Table 2 shows the intervention limit, initial Tag value (relevant for 1965, the peak of ^{137}Cs deposition from global fallout), the short-term ^{137}Cs critical load and long-term Tag value (relevant for 1986, prior to the Chernobyl accident) for reindeer and moose meat, and cow milk. Initial and long-term Tag values for reindeer and cow milk have been derived by integrating geo-referenced measured ^{137}Cs activity concentrations from the AMAP database with predicted ^{137}Cs ground deposition. Due to a lack of geo-referenced measured ^{137}Cs activity concentrations in moose meat, a initial Tag value of 0.02, derived from a literature survey performed in the SAVE project (Howard *et al* 1999), has been adopted; an ecological half-life equal to the physical half-life of ^{137}Cs has been used to estimate a long-term Tag value for moose meat relevant to the period prior to the Chernobyl accident. Using the values assumed in Table 5.2, it is possible to estimate the dependency of the ^{137}Cs critical load following the Chernobyl accident upon the existing ^{137}Cs deposition from global fallout (Figure 5.7). Because of the high initial Tag value for reindeer meat the associated short-term ^{137}Cs critical load is low, indicating that reindeer meat is a food product that is vulnerable to ^{137}Cs deposition. Cow milk, which has a low intervention limit and initial Tag value, is moderately vulnerable to ^{137}Cs deposition. The relatively short effective ecological half-life of ^{137}Cs transfer to cow milk also suggests that cow milk is relatively insensitive to the level of existing ^{137}Cs deposition. Conversely, moose meat, which has a relatively high intervention limit and a relatively low initial Tag value suggesting that in the short-term moose meat is relatively resilient to ^{137}Cs deposition. However, the predicted ^{137}Cs critical load after the Chernobyl accident is highly sensitive to the existing level of ^{137}Cs deposition.

Table 2. Assumed intervention limit, initial Tag, short-term critical load and long-term Tag for reindeer and moose meat and cow milk in Arctic Norway and north west Russia.

Product	Intervention limit (Bq kg^{-1})	Initial Tag (m^2 kg^{-1})	Short-term critical load (Bq kg^{-1})	Long-term Tag (m^2 kg^{-1})
Reindeer meat	3000	1.5	2000	0.2
Moose meat	3000	0.02	150000	0.0124
Cow milk	370	0.01	37000	0.0006

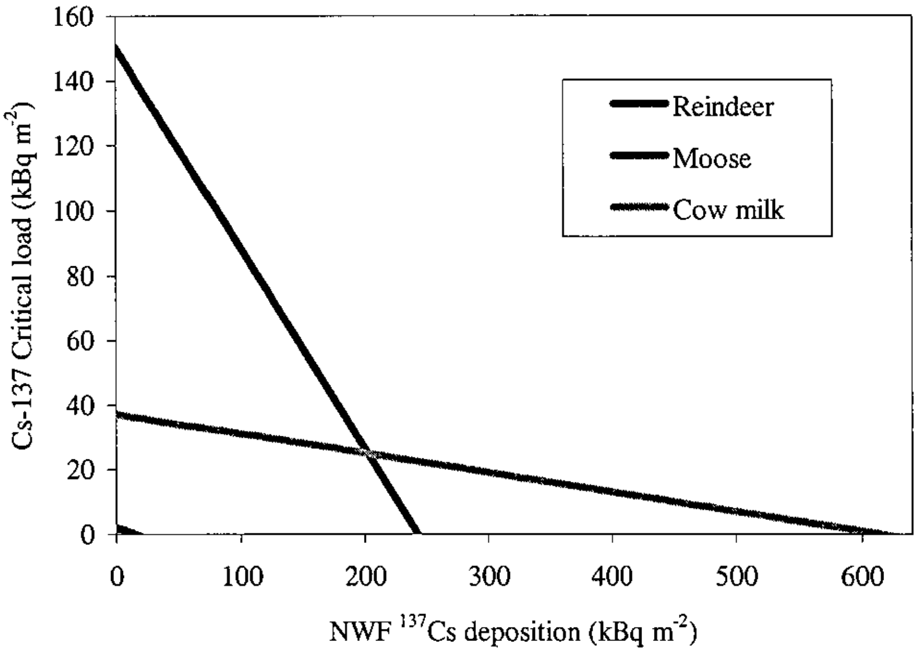


Figure 7. Dependency of estimated ^{137}Cs critical load following the Chernobyl accident upon existing ^{137}Cs deposition from nuclear weapons fallout.

Therefore, the critical loads approach for radionuclide deposition outlined above may well provide a practical method for the identification of areas vulnerable to radionuclide deposition. The development of critical load maps prior to an accident may provide a useful tool for emergency response following any potential accident and would be used to identify those areas where countermeasures may be required. The approach could be further extended to allow the optimisation of limited countermeasure resources to those areas which would receive the greatest benefit.

The approach outlined above is very simplistic. The transfer of radiocaesium is highly variable and the example above used single Tag values for the initial and long-term for each food product. The selection of appropriate Tag values is essential to the estimation of critical loads. However, it can be difficult to derive representative Tag values due to the lack and quality of available data. In the example above, Tag values were estimated by integrating measured ^{137}Cs activity concentrations from the AMAP database with predicted ^{137}Cs ground deposition from global fallout, or, in the case of moose meat, from a literature survey. The variation in the transfer of radionuclides can be partially explained by environmental factors such as soil type and land management practices. If spatial data of sufficient resolution and quality can be obtained, the spatial variation in ^{137}Cs critical load could be quantified. Furthermore, more mechanistic approaches for the modelling of the spatial variation in the transfer of radionuclides (e.g. Howard *et al.* 1999) could be adopted if data on the spatial variation in soil properties affecting the transfer of radionuclides are available.

Further improvements to the application of critical loads to assess vulnerability of Arctic areas to radionuclide deposition are also desirable. The ^{137}Cs critical loads estimated above do not account for:

- variation in the production and harvesting of the different food products;
- the time when animals are grazing outside, which will be restricted by the short growing season in the Arctic;
- the use of stored, uncontaminated feed, which will delay the contamination of some food products following any accident; and
- the variation in the growing season, management and slaughtering and hunting/gathering of semi-natural and natural foodstuffs.
- If sufficient spatial data can be obtained on the above factors they can be included in the assessment and identification of vulnerable areas in Arctic Norway and north west Russia.
- Information on the spatial variation of:
- soil type and soil properties affecting the transfer of radiocaesium and radiostrontium
- land cover and land use to allow the identification of areas for the production of different food products

agricultural production is currently being collated for Arctic Norway and north west Russia at the best possible scale. This data will be integrated within a GIS to allow the identification of areas that are vulnerable to radiocaesium and radiostrontium deposition. The models developed will be validated using historical data of the impacts of radionuclide deposition from atmospheric nuclear weapons tests and the Chernobyl accident. Scenarios of potential radionuclide contamination arising from sources in the Arctic will be used to quantify the impacts to Man.

3.2.2 Publications and papers

B Howard, S. M. Wright, C.L. Barnett, L. Skuterud, P. Strand (1999). Strand Estimation of critical loads for radiocaesium in the Arctic. In: Environmental Radioactivity in the Arctic. Ed. by Per Strand and Torun Jølle, NRPA, Østerås, pp. 85-87.

3.3 Research and Technical Centre "Protection" (RTCP/IRH)

3.3.1 Objectives and planned actions

- Collation of dietary information and habit survey data (IRH, NRPA)
- Identification of knowledge gaps (ALL)
- Sampling strategy - questionnaire preparation (NRPA/IRH)
- Field work - food contamination data, diet and habit survey, whole body counting (NRPA/IRH)
- Development of the radioecological model: Internal dose parameterisation (IRH; NRPA) and External dose model application (IRH)

3.3.2 Contributions of individual partners

During first year of the project performing the following experimental and intellectual works were done by RTCP/IRH:

- Development of radioecological model of human exposure from the fallout of radioactive fission products in conditions of Arctic environment and its parameterisation with regard of internal and external exposure;
- Collation of dietary and habit information relevant to indigenous people of the Russian Arctic (European part);
- Field work in the Mezen district of the Arkangelsk region, Russia, including sampling of soil and natural and agricultural food products, dietary survey and whole body counting of local residents, collection of relevant ecological, demographic and production data

3.3.3 Problems encountered

No problems encountered with regard of experimental work. As for modelling, there is significant gap of both theoretical and experimental data relevant to parameterisation of radionuclides deposition on snow cover and subsequent interception of radionuclides by lichen which is the key link in the important Arctic food chain "lichen-reindeer-man". As Arctic environment is covered with snow during most time of the year lack of these data may lead to significant increase of the Arctic model prediction uncertainty. There is real need in special experiments to study radionuclide interception and retention on lichen after their deposition on snow and subsequent snow melting.

3.3.4 Publications and papers

- Balonov M., Golikov V., Logacheva I. and Strand P. (1999) Radioecological model of internal exposure of the Man with caesium radionuclides in the Russian and Norwegian Arctic environments. In: Environmental Radioactivity in the Arctic. Ed. by Per Strand and Torun Jølle, NRPA, Østerås, pp. 85-87.
- Travnikova I.G., Bruk G.Ya., Balonov M.I., Shutov V.N., Skuterud L. and Strand P. (1999) Assessment of Current Exposure Levels in Different Population Groups of the Far North. In: Environmental Radioactivity in the Arctic. Ed. by Per Strand and Torun Jølle, NRPA, Østerås, pp. 289-291.
- Shutov V.N., Bruk G.Ya., Travnikova I.G., Balonov M.I., Kaduka M.V., Basalaeva L.N., Skuterud L., Mehli H. and Strand P. (1999) The Current Radioactive Contamination of the Environment and Foodstuffs in the Kola Region of Russia. In: Environmental Radioactivity in the Arctic. Ed. by Per Strand and Torun Jølle, NRPA, Østerås, pp. 307-309.

3.3.5 Outline plans for next year

- Preparation of the deliverable: Database of dietary and habit information relevant to indigenous people of the Russian Arctic (European part);
- Completion of the radioecological model development and parameterisation;
- Adaptation of the model for integration into GIS;
- Field work in the Nenets region

3.3.6 Scientific results

Collation of dietary information and habit survey data:

Dietary information and habit survey data relevant to indigenous people of the Russian Arctic (European part) are collected from the published literature. Additional information was collected during field works in the Kola region (1998-1999) and Arkangelsk region (1999) including social and demographic data, description of dwelling type, relevant natural and climate data. Personal interviewing of inhabitants was performed according to special questionnaire – see below.

3.3.7 Identification of knowledge gaps:

Knowledge gaps were discussed and identified during first project meeting in St. Petersburg, December 1998, - see Minutes, Appendix 3.

Sampling strategy - questionnaire preparation:

The preparation of questionnaire for fieldwork used for Arctic inhabitants, 1998 and 1999, see Appendix 2.

Field work – food contamination data, diet and habit survey, whole body counting

The expedition in the Arkangelsk region, Mezen district, located on the Northwest coast of the White Sea was undertaken in August 1999 (V. Shutov, G. Bruk and I. Travnikova). At the end of June M. Balonov and I. Travnikova preliminary visited Arkangelsk and agreed with local authorities on the field works in 1999 and 2000 with participation of foreign partners.

During the field work three villages were visited where population is involved in reindeer breeding. 75 persons were interviewed on their food habits according the questionnaire above and 85 persons were measured for ^{137}Cs content in the body. Soil samples as well as 6 grass mixture samples, 10 lichen and 10 mosses samples, 33 mushroom samples of 10 species and 8 samples of wild berries of 3 species were collected in 4 plots located by GPS. Samples of reindeer meat, lamb meat, beef, cow milk, goat milk, locally produced vegetables and fish of 6 species were purchased from local inhabitants. The data on natural and climatic conditions, vegetation, demographic and production data were collected from local institutions.

Collected samples are being analysed and databases as well as expedition report are in preparation. The report is expected to be prepared in winter 2000.

Development of the radioecological model: Internal dose parameterisation and External dose model application

In the framework of the present Project the main purpose of the direction 'Modelling' was the development a spatially variable biophysical model to calculate internal and external doses from radioactive contamination of Arctic environments by radioactive caesium (^{134}Cs and ^{137}Cs) and strontium (^{90}Sr). The key elements in an Arctic model should be the incorporation of relevant northern food chains including the terrestrial lichen-reindeer-man chain, freshwater ecosystem, forest ecosystem with mushrooms and berries, local agricultural ecosystem, and external dose. The model should have a unified structure for different Arctic regions and take into account regional and social differences in agriculture, dietary habits and use of forest and freshwater environments. It should therefore be supplied with sets of national and regional site-specific parameters relevant to both internal and external exposure of the Man.

Structure of model of an internal exposure

The scheme of the model is shown in Fig.1. The input data are the local time-integrated concentration of activity in air, the activity deposited during precipitation, and the amount of rainfall during rainfall event. These data can be measured by environmental monitoring systems, or predicted with atmospheric dispersion and deposition models. The model include relevant northern food chains: the most important terrestrial lichen-reindeer-man chain, local agricultural chain (in the present version - only cow milk and beef), freshwater chain, and forest chain with mushrooms and berries. For the ingestion pathway, all relevant transfer processes between soil, plants, and animals, such as interception, translocation, root uptake, animal feeding are considered. The output results are the time-dependent and time-integrated internal doses, and the activity concentrations in plants and animal food products up to 70 y after deposition. Doses are estimated for three groups of population: reindeer-breeders and their families; inhabitants of large industrial cities and rural inhabitants of villages and small settlements who are not involved in reindeer breeding. Corresponding consumption rates and dose factors are applied to calculation the lifetime doses of these groups.

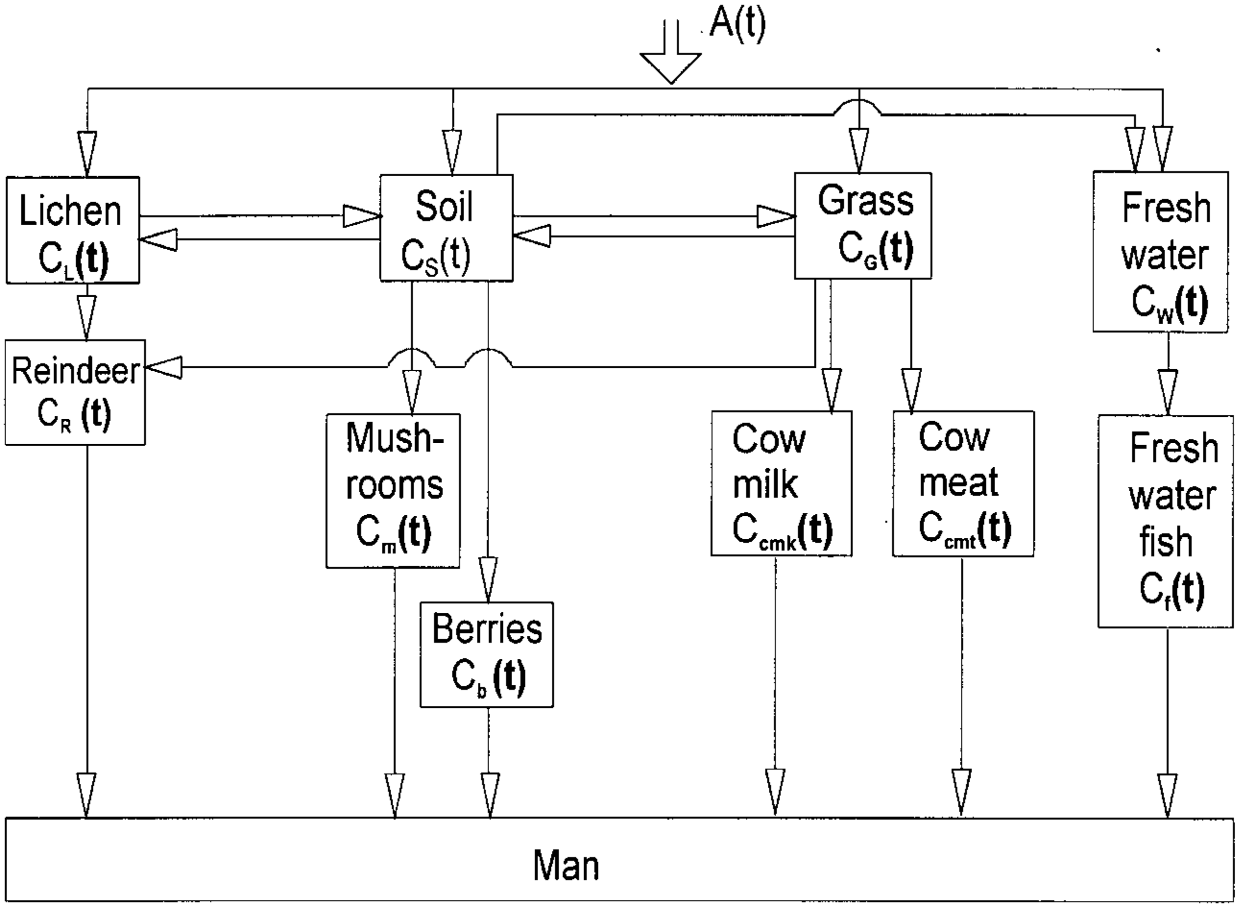


Figure 1. Scheme of the exposure pathways considered in the model of internal exposure

Above-mentioned approach and its computational model with set of equations and default parameters values were implemented as a computer program. The program was written by using the Object-Oriented language (Borland Delphi3). The program has a context dependent help, standard friendly interface for work with many overlapped windows by using mouse and keyboard. With the purpose of an estimation of parameters for the most important terrestrial lichen-reindeer-man chain the special computer program permitting to simulate continuous radioactive depositions as a result of nuclear-weapon tests was developed. Feature of this program is the opportunity to estimate parameters of model by comparison of calculation results with experimental data by help of the least squares method.

Model of external exposure

As the basic model, we chose the model for external exposure to population living in the temperate areas contaminated due to the Chernobyl accident. We developed this model earlier within the project JSP5 - Pathway Analysis and Dose Distributions (EC Report EUR 16541, 1996).

The information necessary for the assessment of the dose in any situation of the external exposure of man includes the following three major blocks:

- parameters relating to the external gamma radiation field;
- characteristics relating to the behaviour of man in this field;
- conversion factors relating the gamma radiation field to the dose in the human body.

As a rule, a model for the exposure of man above a grassy virgin plot of soil is used as a base model, and the absorbed dose in air at a height of 1 m above ground $\dot{d}(t)$ as a measure of the radiation field. This field is influenced by several main factors such as the surface activity of deposited radionuclides, their initial penetration, radioactive decay, the process of vertical migration of long-lived radionuclides in the upper soil layer and the presence of snow.

In anthropogenic media, (settlement with its buildings, roads, etc.) the parameters of the radiation field change. In the model, this fact is taken into account by means of location factors f_j. These are defined as the ratio of the dose rate at point j in a settlement (or its vicinity) attributable to the gamma radiation from radioactive deposition to the analogous value above an open virgin soil plot. The behaviour of a man in the field of radiation is described by means of occupancy factors p_{ij}, which are defined by the period of time spent by representatives of the i-th group of the population in the j-th point of a settlement. Finally, the third block of information required for assessment of the dose from external exposure is represented in the model by conversion factors k_i , which relate measurable values such as absorbed dose in air to the human exposure - the effective dose.

This model is intended for the assessment of average organ doses and effective external dose to man in anthropogenic media from the gamma radiation of Cs-137 and Cs-134. The basic spatial structure for calculation of the external dose is a separate settlement and its vicinity. Both the dose rate and doses accumulated over an arbitrary time interval (up to the assessment of the lifetime dose) can form outputs. These values may be calculated for a number of population groups. The equations of the model for the rate of the effective dose of external gamma radiation for the representatives of the i-th population group $\dot{E}_i(t)$ at the time t after deposition of a caesium isotopes is written in the following way:

$$\dot{E}_i(t) = \dot{d}(t) \cdot k_i \cdot \sum_j f_j \cdot p_{ij} \tag{1}$$

$$\dot{d}(t) = r(t) \cdot A^{137} \left[g_{137} \cdot \exp(-\lambda^{137} \cdot t) + g_{134} \cdot \frac{A^{134}}{A^{137}} \cdot \exp\left(-\lambda^{134} \cdot t\right) \right] \tag{2}$$

$$r(t) = p_1 \cdot \exp(-\frac{\ln 2}{T_1} \cdot t) + p_2 \cdot \exp(-\frac{\ln 2}{T_2} \cdot t) \tag{3}$$

A^k is the activity deposited per unit area on a reference site (normally lawns or meadows) on the moment of the end of depositions, g_k the gamma dose rate in air per activity per unit area for a initial distribution of the caesium radionuclides in the ground, λ^k the decay constant. The function $r(t)$ is the gamma dose rate in air at the reference site divided by the gamma dose rate in air for the initial distribution.

Numerical values for the parameters of the model, for assessment of the external effective dose to the population, were determined on the basis of results of on-site dosimetric investigations after the Chernobyl accident. Some of these parameters, for example, values of conversion factors k_i are rather universal and can directly be used in a given task, others should be defined follow-up, in view of specific behaviour and habitat of the population of Arctic Region, especially reindeer- breeders and their families.

The effective dose of external exposure accumulated during any time interval can be determine by integration of Equation 1, taking into account Equations 2 and 3. The presence of snow cover during winter is not modelled explicitly in equation (1). Therefore, to account for the influence of a snow cover on the value of annual effective dose of the external exposure integral for a calendar year should be multiplied by special factor. Its value for different Arctic areas is important parameter of the model.

Estimation of the model parameters

The basic data source for an estimation of parameters of the model of internal exposure are the data from the programs of radiation monitoring performed in the Arctic areas, both after the global fallout and the Chernobyl accident. These data have been collated, through extensive collaboration, in the AMAP data centre at NRPA. The basic difficulties at usage of these data for solving of the problems concerning the present project are:

- incompleteness of the data in space and in time;
- difficulties of the estimation of the model parameters for short-term deposition on the basis of data obtained at continuous deposition;
- practically complete lack of the data about deposition on snow and subsequent contamination of environmental objects.

Except for the above-mentioned data sources for a parameterisation of models the results of the field examinations of the environmental objects (soil, grass, lichen, mushrooms, berries), data about dietary habits and modes of behaviour of different groups of the population, data about shielding properties of dwellings collected in our recent expeditions will be used. Now this work is continued. The parameterisation of models of an internal and external exposures is planned to be finished in December, 1999, and March, 2000, accordingly.

3.4 Russian Federal Service for Hydrometeorology and Environmental monitoring / Regional Centre «Monitoring of the Arctic» HYD/RCMA

According to AVAIL technical annex main project objectives for RCMA in 1999 were:

- preparation of improved review of radioactive contamination of European part of Russian Arctic (RCMA)
- collecting and generalisation of demographic information on territories covered by geographical (RCMA)
- borders of the project;
- generalisation and mapping of modern information about agricultural using of soils and about reindeer pastures areas (RCMA).

RCMA fulfilled all missions dedicated to the first year of the project. Basing on information materials of AMAP 1 Phase considering data represented in annual official reviews of Roshydromet: «Radiation Situation in the Arctic area» and «Russian Federation Environment Contamination» improved version of «Review of Radioactive Contamination of European Part of Russian Arctic» (work package 1 of the project) is prepared. Available demographic statistical information on territories of Murmansk county, Nenets Autonomous Region and Mezen district of Arkangelsk county is collected and digitised.

Information on Murmansk county is fully digitised and prepared to transmitting into digital map (work package 1 of the project).

Basing on official topographic maps with scale 1:500,000 digital map of Kola peninsula is prepared in the form of layers according to types of topographic information, including:

- coastline of the sea, land, adjacent part of the sea, geographical names;
- terrestrial water objects;
- swamps;
- elements of the landscape;
- areas of woods and bushes;
- settlements.

Information on condition of soil and vegetation cover in the Kola peninsula and Nenets Autonomous Region is collected and digitised.

Information on the Kola peninsula is prepared in form of digital electronic maps of scale 1:500000, using as topographic base of layers of digital topographic map: coastline, terrestrial water objects (work package 2 of the project).

Information on agricultural using of land and on reindeer pastures areas in Murmansk county and NAR is also collected and digitised. Information on Murmansk county is also prepared in form of digital electronic maps of scale 1:1,000,000 and 1:500,000 (work package of the project 2).

All map information is presented in MAPINFO 5.0. formats. All graphic information is connected to real geographic coordinates. Every layer contains tables of object characteristics, which make it possible to create thematic maps.

Working sets are prepared to transfer maps for printing straightway from MAPINFO. When necessary they can be put in text files of WORD format and others. For convenience of printing names of working sets include names of pictures. Full list of maps which were prepared in 1999 is presented in Appendix to report.

In 2000 (second project year) it is planning to fully complete digital mapping of information on Nenets Autonomous Region and Mezen district of Arkangelsk county, and also to digitalise and

prepare as digital map information on thickness of snow cover and precipitation amount in this area.
Completing this work will let other participants of the project (NRPE, IRH) to use mentioned information in operative dose models in the Arctic for all territories included in the project.

Review of radioactive contamination of the European part of the Russian Arctic

«A Review of radioactive contamination of the European Part of the Russian Arctic» is compiled using materials of report of the Russian experts for AMAP «Radioactive contamination in the Russian Arctic» and added to materials of annuals «Radiation situation on the territory of Russia and adjacent countries» and «Reviews of pollution of Russian Federation environment» for 1997-1998.

The review contains information on sources of radioactive contamination of the territory, transport of radionuclides in environmental compartments, levels of contamination of environmental components and influence of increased levels of radionuclide activity on the population.

Modern picture of distribution of radionuclides in environmental compartments of European Part of the Russian Arctic has being formed under influence of global and local antropogenous sources of radioactive contamination.

The global sources includes:
- global fallout from atmospheric nuclear weapons testing all over the Northern hemisphere,
- fallout from the Chernobyl accident in the European area,
- marine transport of liquid radioactive wastes from nuclear fuel reprocessing plant in Sellafield.

The most important local sources are:
- Novaya Zemlya nuclear weapons test sites,
- peaceful nuclear explosions in and near the Arctic area,
- dumping of solid radioactive wastes including nuclear reactors and vessels in the Barents and Kara Seas,
- nuclear storage in coastal bays of the Kola peninsula,
- decommissioning of nuclear-powered and auxiliary vessels.

Sources of less importance:
- river transport of released radionuclides to the Arctic seas,
- the nuclear power plants located in and near Arctic,
- operation of the nuclear ice-breaker fleet from its Murmansk base and the Russian Northern Fleet located in Kola harbours,
- Naval accidents including the sunken Komsomolets submarine.

The main source of radionuclides discharge to the territory under study has been global atmospheric fallout. Radioactive contamination of the territory attained maximum values in the 1960s primarily as a consequence of atmospheric nuclear weapons testing. In 1970s and early 1980s, liquid releases from the Sellafield nuclear fuel reprocessing plant significantly contaminated the Barents Sea marine environment. Global fallout from the Chernobyl accident in 1986 made additional significant contributions to radionuclide contamination of European Part of the Russian Arctic. Contribution of other sources of radionuclide contamination is negligible. Since then, levels of radionuclides have been in general decline.

The review contains data on radionuclide activity levels in atmospheric air and precipitation, sea- and freshwater and bottom sediments, soils, sea and freshwater biota, terrestrial vegetation and mammals. Besides, it contains data on radionuclide activity levels in tissues and media of man organism, sources and dynamic of absorption of radiation doses by population.

Freshwater and terrestrial ecosystems are mostly influenced by fallout and input of radionuclides on the territory. From the point of view of entering of radionuclides in the man organism the most significant pathway is the *lichen (mushroom) - reindeer meat - man* food chain.

In contrast, marine ecosystems suffered significantly less, due to considerable dilution effect and low transfer rates.

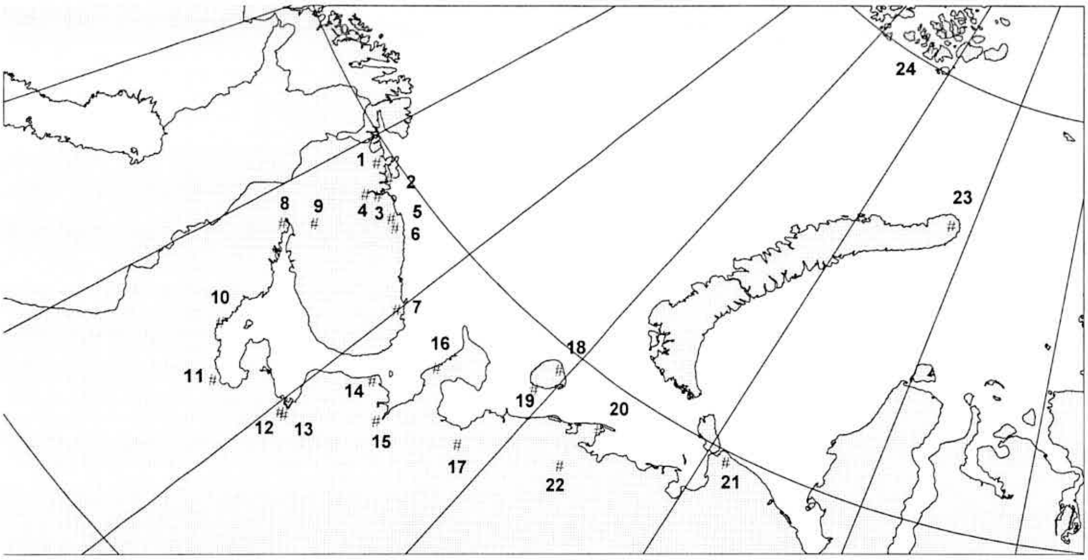
Rates of internal and total exposure to population varies with lifestyle, dietary habits and place of residence. Consumption of local natural food products provides the principle contribution to human internal exposure.

It is fixed that consumption of local reindeer meat, freshwater fish and mushrooms leads to increased internal and total exposure of inhabitants of European Part of the Russian Arctic. As far as local population diet is significantly based on consumption of these food products this population group is exposed to maximum risk. Inhabitants of large Arctic cities are exposed to minimum risk because their diet is based on imported food. Their risk level is comparable to that of temperate latitudes.

Besides text part this review contains 43 figures (including maps) and 39 tables, describing spatial and temporal trends of changing of radionuclide contamination of the environmental compartments.

Examples of representation of information in the review are given below (Figures 1-5).

Besides, under generalisation of available information a digital map of the total ^{137}Cs deposition on the territory of the Kola peninsula (scale 1:500,000) in Map Info format was prepared. A demonstration version of this map is presented in Figure 1, Appendix 1 (scale 1:3,000,000).



1. Pechenga
2. Tsip-Navolok
3. Polyarnoe
4. Murmansk
5. Teriberka
6. Dal'nie Zelentsy
7. Iokan'ga
8. Kandalaksha
9. Khibiny
10. Kem'
11. Onega
12. Arkangelsk
13. Kego
14. Morzhovets
15. Mezen
16. Shoina
17. Nizhnyaya Pesha
18. Severny Kolguev
19. Bugrino
20. Khodovarikha
21. Amderma
22. Naryan-Mar
23. Cape Zhelania
24. Heis Island

Figure 1. Coastal and island sites conducting daily monitoring of radioactive fallout

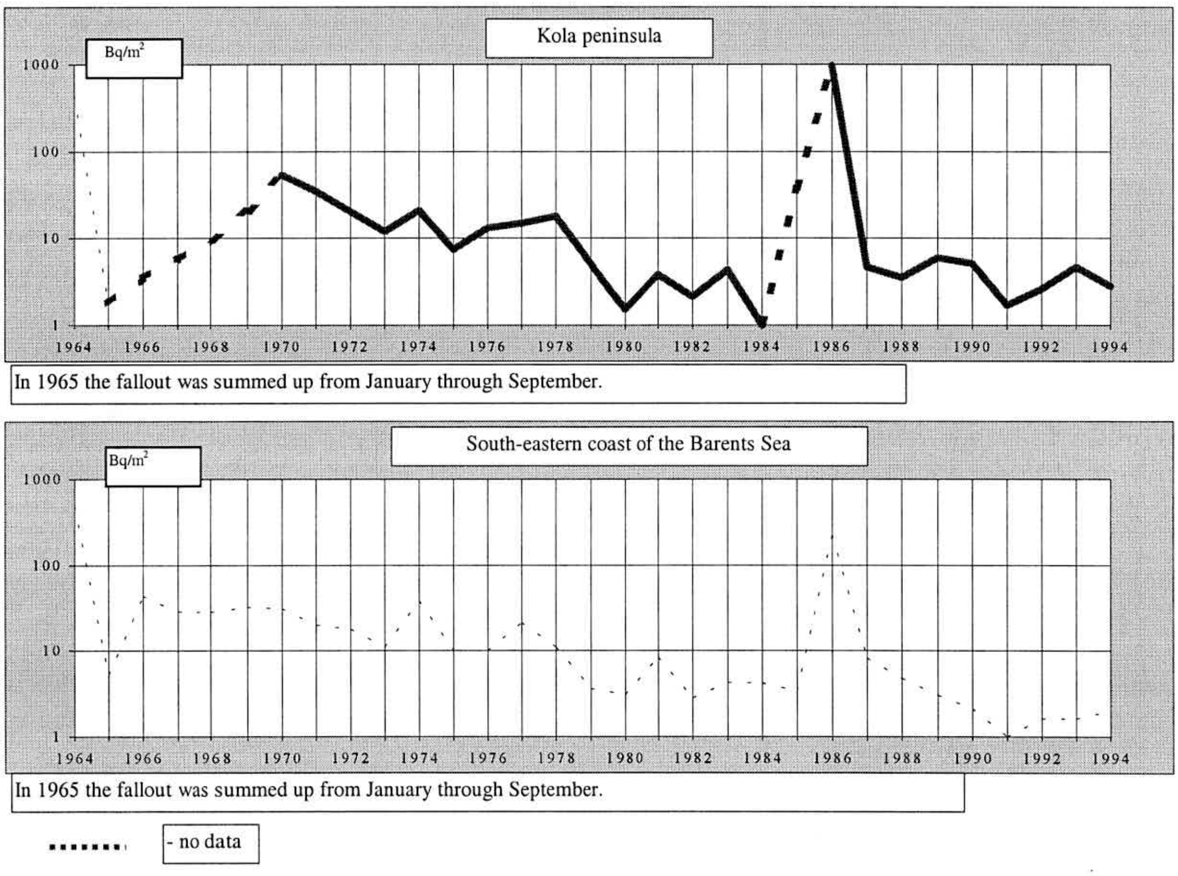


Figure 2. Total annual atmospheric fallout of ^{137}Cs, 1961-1994 (adopted from Tsaturov et al., 1997).

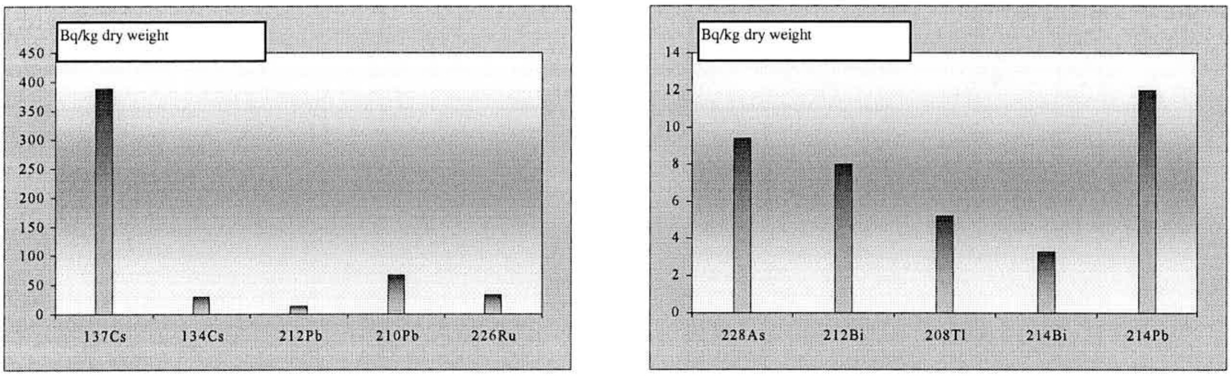


Figure 3. Mean activity concentrations of radionuclides in lichen of the eastern Kola peninsula, 1993 (adopted from Matishov et al., 1994b).

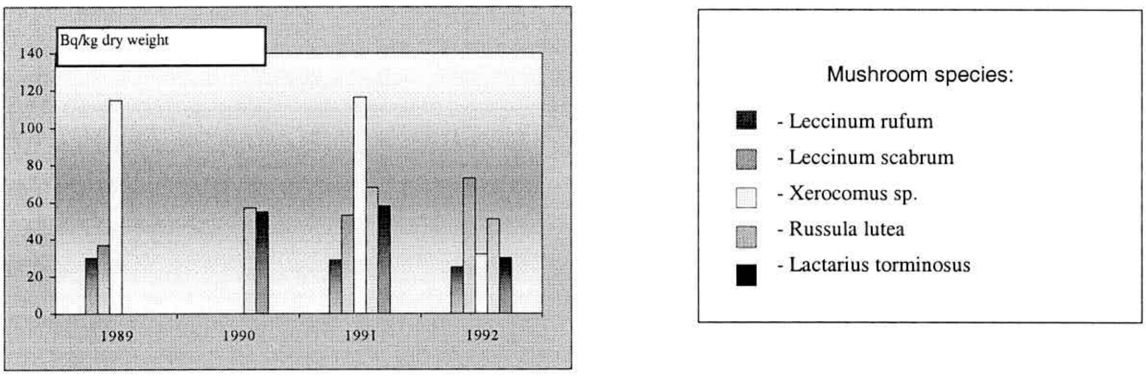


Figure 4. Mean activity concentrations of ^{137}Cs in different mushroom species of the Kola peninsula, 1989-1992 (adopted from Miretsky, 1994).

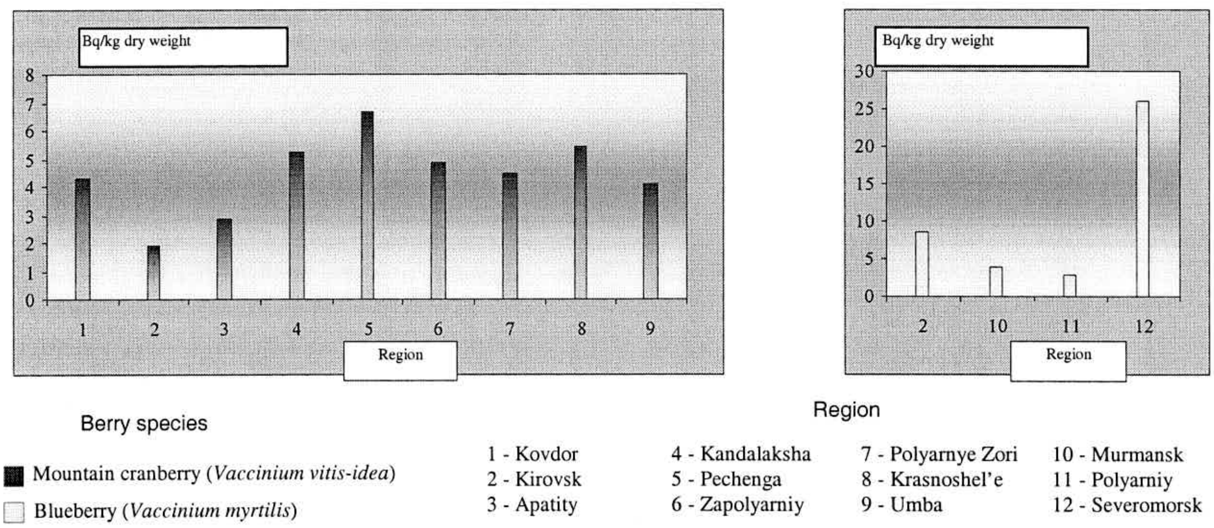


Figure 5. Mean activity concentrations of ^{137}Cs in berries of regions of the Kola peninsula, 1987-1991 (adopted from Matishov et al., 1994).

Demographic information

In framework of the first year works included into the WP1 «Synthesis and evaluation of currently available information» the available official demographic information on the Russian Arctic areas, covered by geographical borders of the project and included Murmansk county, Nenets Autonomous Region and Mezen district of Arkangelsk county, was collated.

Information on Murmansk county is completely summarised and currently it is mapping for preparation of the digital thematic layers in the system GIS Map Info. The information on other territories will be digitised in the second year of the project.

Digitised information contains:

- general population number according administrative sectors;
- breakdown by nationality, age and sex;
- number of women of bearing age and number of children aged under 4 years;
- birth-rate, death-rate and natural increase or decrease of population;

Abovementioned characteristics are indicated for towns and districts of the Murmansk county.

Short review of current demographic situation in the Murmansk county is presented below.

According to different evaluations, there were from 13 to 15 thousand inhabitants in Kola peninsula in 1913.

Accordingly the data on 1.01.1993 the general population in the Murmansk county consisted of 1187.4 thousand people. Average density of population – 8.3 inhabitants per 1 km^2. In comparison to other regions of Barents region, Murmansk county is mostly urbanised: 93% of residents live in cities. The residents of Murmansk City, the administrative centre of the county, are about 40% of population as a whole.

Settling of urban inhabitants of the region has its own peculiarity: each town or settlement of urban type administratively consists of several settlements which are remote sometimes for many kilometres from each other.

Major portion of the population is concentrated in the region located between cities of Murmansk and Kandalaksha.

Population is resided along the railway and coastline. Moving away from the coastline and railway, population density abruptly reduces. In rural area the inhabited sites including nearest agricultural lands (in the distance of 4 km from centres of settlements), look like little spots. Extended territories have not any permanent network of settlements, however, there are a few totally pristine areas In peninsula because of almost all tundra is used for reindeer pastures.

Reducing of general population in the Murmansk county mostly caused by emigration process than decline of the birth rate was registered in the last years. The emigration happens as result of unemployment and sharp decrease of income, and also re-emigration to the republics of the former USSR which recently got independence. Average life expectancy among men is less than 60 years (in some districts even less than 50 years), and among women it is a little bit more than 70 years.

The most numerous nationality in the county are Russians consisted of 83% from total number of population. Second ethnic group on quantity are Ukrainians (9.0%), then Belorussian (3.3%) and Tatars (1.0%). Representatives of other nationalities included Mordva, Karelians, Sami, Komi, Finnish and Mari also live in the county. Sami are indigenous population of the Kola peninsula. Number of representatives of this nationality in the Murmansk county according the Census of 1989 was 1615 people, mostly living in Lovozero district.

Sami were nomadic in the past, but nowadays are totally settled people. About 20% of Sami are urban peoples. The Lovozero district's population also is characterised by the considerable percent of Komi reindeer-breeders, who came here in the end of XIX century from Arkangelsk county.

Table 1. Population of the Murmansk county (according data on 01.01.93)

Cities	Population		Districts	Population
Murmansk	468,300		Pechenga	97,500
Polyarny	29,200		Kovdor	36,300
Severomorsk	96,500		Kola	73,400
Apatity	87,500		Lovozero	17,900
Kandalaksha	77,600		Tersky	10,000
Kirovsk	48,500			
Monchegorsk	72,700			
Olenegorsk	46,900			
Polyarnye zori	25,100			
Total				1,187,400

Table 2. Urban, rural and indigenous population of the Murmansk county (according Census of 1989)

Indigenous population	1,899
% indigenous population	0.16
Urban population	1,070,970
% urban population	91.96
Rural population	9,3616
% rural population	8.04
Total population	1,164,586

Table 3. Number of small numbered North ethnic groups in Murmansk county (according Census of 1989)

Nationality	Population		Nationality	Population
Sami	1615		Chukchi	2
Enets	4		Yupik	3
Nenets	176		Yukagir	3
Khanty	10		Selkup	1
Nganasan	5		Chuvan	9
Dolgan	18		Koryak	5
Even	10		Mansi	18
Evenk	20			
			Total	1,899

Table 4. Breakdown of Murmansk county population by age (according Census of 1989)

Under 16	24%
From 16 to 60 years	66%
Older than 60	10%

Topographic map

In 1999 RCMA has used digital topographic map of the Kola peninsula to prepare thematic digital maps (demographic, of soils, vegetation, agricultural use of land, areas of reindeer pastures etc.), and also to estimate quantitative characteristics of box models on the following steps of project realisation.

Digitising of map layers was carried out in GIS Map Info. As a paper basis they used official topographic maps of scale 1:500,000 of Kola peninsula published by State Int. «Aerogeodezia» Roscartography of RF in 1990-1994. Spatial borders of digitising region coincided with borders of administrative dividing of the Murmansk county (see Fig.6).

Digital map is made as layers according to types of topographic information:

- coastline of the sea, land, adjacent part of the sea, geographical names;
- terrestrial water objects;
- swamps;
- some elements of the landscape;
- areas of woods and bushes;
- settlements.

Moreover there are divided the following types of objects and their characteristics:

Coastline of the sea, land, adjacent part of the sea, geographical names:

- sea areas (the White and Barents Seas)
- areas of sea islands
- areas of draining zones (draining coastline (ebb and flow line)).
- names of seas, bays, straits, peninsulas, islands, ranges, mountains.

Terrestrial water objects:

- rivers, permanent streams;
- rivers, drying out streams;
- river, underground or disappearing stream (part of river, stream);
- surface channel working;
- rapids, shoals;
- ford;
- waterfalls;
- spring, spring uncultivated;
- names of rivers and lakes

Swamps:

- swamps passable;
- swamps relatively overgrown.

Areas of woods and bushes:

- wood thick and high (usual);
- wood sparse and high (sparse growth of trees);
- wood thick and undersized (dwarf);
- wood sparse and undersized;
- cleared wood;
- burnt or dead wood;
- wood verdure, wood arboretums and young plantings with height below 4m;
- dense bushes brakes;
- grass meadow vegetation;
- narrow wood line and protective afforestations;
- narrow bushes line or hedge;
- separate bush, group of bushes.

Elements of the landscape:

- stone scattering and detritus surface;
- stone surface (outcrop of monolith rocks);
- surface with mounds;
- flat sand.

Settlements:

- big city;
- settlement of urban type;
- settlement of rural type;
- other settlements;
- constant settlement of yurts, chums etc.;
- the names of settlements.

Simultaneously with digitising, data bases of digital layers were being prepared in form of Map Info tables. Tables contain metric and semantic information about all objects of the map layer. Structure of Map Info tables is given below.

Table 1. Structure of tables of area and other objects of Map Info digital layers.

Field Name	Type	Content
ID	integer	Ordinal number of object in database - whole positive number. Presence of the same ID in both tables is impossible (see although description of field MAPID). Consecutive increase of numbers is not guaranteed.
DESCR	char	Description of type of object (for example «lake»)
NAME	char	Personal name of the object or empty line, if there is no name
KLS	integer	KLS=1 , if code is from classification of objects; KLS=2 , if code is from classification of characteristics.
LOC	char	Type of localisation of object. It can take the following meaning: "P" - point object (Point); "L" - polyline object (Polyline); "R" - region object (Region); "T" - text (Text); "N" - object without graphic presentation (None).
POINTX	float	Coordinate X of centre of point object, shown on the map as non-scaled symbol. For object with type of localisation different from the point one, always contains 0.0.
POINTY	float	Coordinate Y of centre of point object, shown on the map as non-scaled symbol. For object with type of localisation different from the point one, always contains 0.0.
OWNER	integer	Object ID , which owes the object.
LAYER	integer	Code of thematic layer which the object belongs to.
MAPID	char	Nomenclature of digital map list.

Digital maps on the Kola peninsula are totally completed. Currently similar work is being carried out for the territory of Nenets Autonomous Region. This work will be completed by the end of the second year of the project (July-August of 2000).

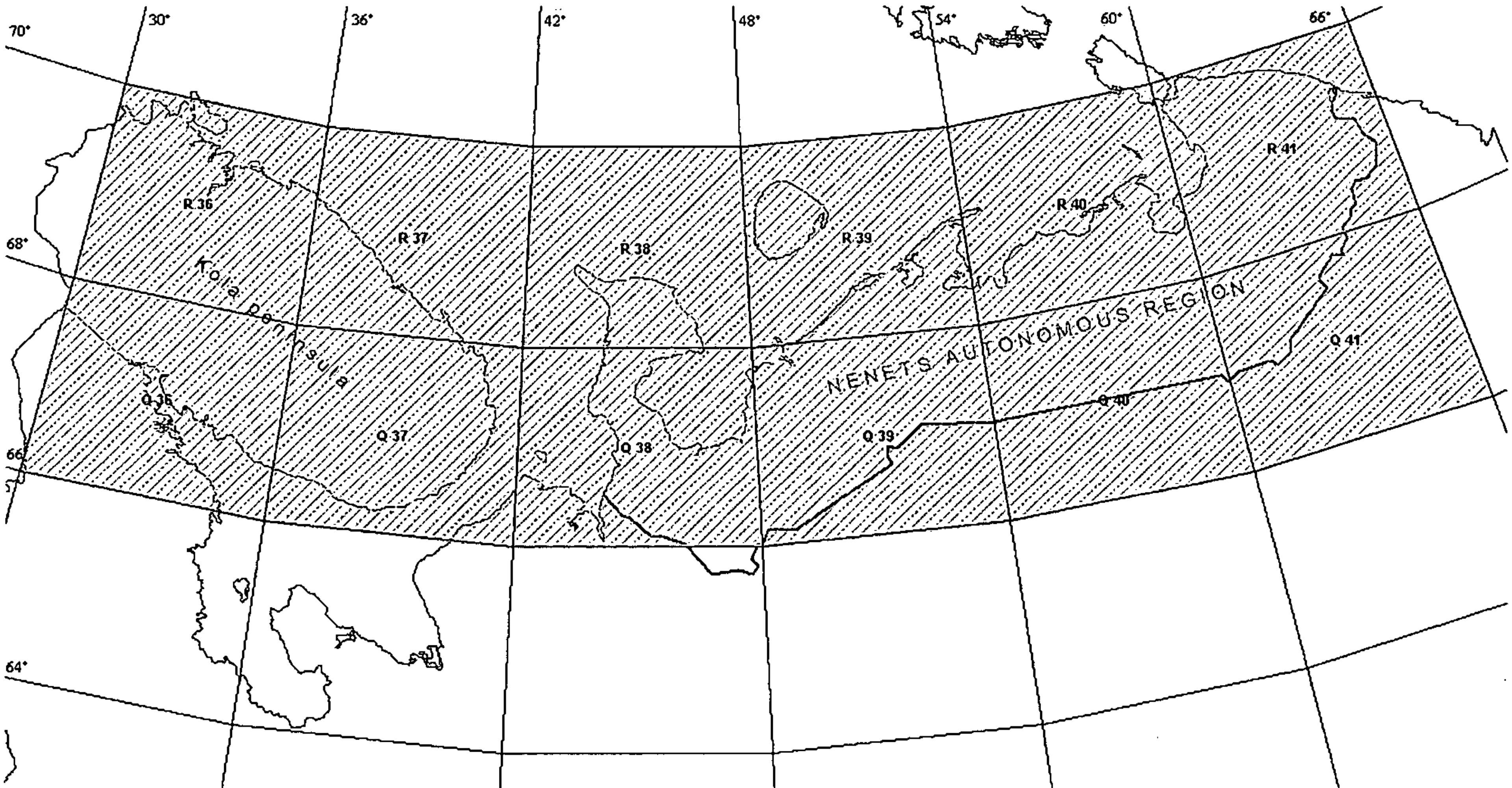


Figure 6. Geographical borders of the area described in AVAIL project and nomenclature of sheets of the official topographic maps of scale 1:500 000

5. Characteristics of soil and vegetation covering

Available information on spatial distribution of predominant types of soils and complexes of vegetation communities on the territory of the Kola peninsula and NAR is collected and digitised during the report period.

For region of Kola peninsula digital thematic maps are prepared in the format Map Info with scale 1:500000, using as topographic basis relevant layers of digital topographic map (coastline, land water objects).

For printing of soil map as illustration to the report, see Appendix I, maps from Map Info is transmitted into Word 97 formats. To reduce the volume of printed copies they accepted printing scale of 1:1,000,000. Moreover, layers of topographic bases were also digitised to scale of 1:1,000,000. Digital maps prepared for work with models have more detailed scale of 1:500,000.

Soil map of the Kola peninsula

Kola peninsula is attributed to the special provinces of the set of soil subdivisions of the European North: Kola province of the podzolic illuvial humus-rich soils of the Eurasian polar region (the area along the northern seashore), and Kola-Karelian province of the reduced illuvial humus-rich podzols of the Central taiga-forest region. Peculiarities of the soil formation in Kola peninsula are near surface and exposed Baltic crystalline shield of predominantly acid bedrock, humid climate, and lack or poorly developed patchy permafrost. These results in relative abundance of non-gleyic soils on the soil cover (podburs and podzolic Al-Fe-humus soils), and relatively reduced position of the different kind of bog soil complexes. Bog soils itself are usually less pronounced in the bog soil complexes.

In the soil map there is spatial distribution of predominant types of soils or soil complexes on the territory of region studied.

The soil complexes description and prints of maps are shown in Appendix I.

Vegetation map of the Kola peninsula

In the botanical-geographic subdivision Kola peninsula belongs to the Kola-Pechora sub-province of the North-European taiga province except for the belt along the northern seashore, which belongs to the Kola sub-province of the European-West-Siberian tundra province. Due to the humidity of climate along with well-pronounced mountain landscapes the plant cover is rather close to that of northern Fennoscandia, especially expressed in the composition of tundra vegetation formations. Quaternary sediments of predominantly sand, gravel and pebble are relatively thin whereas acid crystallic bedrock of the Scandinavian shield are widely exposed over the peninsula. These results in the relatively low abundance of the bog vegetation, which occurs usually in the complexes with predominance of forest or (and) tundra formations.

On the vegetation map there is shown spatial distribution of predominant types of vegetation and vegetation communities on the territory of study region.

The description of vegetation cover complexes in the vegetation maps are shown in Appendix. I

Agricultural and use of land

Almost all Murmansk county is situated to the North of the Polar Circle. Its square is 144,900 km^2. 140 km^2 is used in agriculture of the region (about 0,1% of the whole territory). Of this arable soils are about 70 km^2.

Predominating part of sown area (62 km^2) is covered by fodder crops. The rest of the area is under potato and vegetables of opened and closed soil.

The main field of agricultural production - is stock-raising (cattle-breeding, fat swine stock and poultry farming). Cattle which is due short pasture period most time spend in stalls, has diary specialisation.

Important marketable field of stock-raising - reindeer-raising (leather and meat) is mostly developed in Lovozero district. In the Kola district sophisticated reindeer-raising station is organised (MOOS). Tundra-wood (wood-tundra) type of reindeer farm is characteristic for the region.

Total square of reindeer pastures (summer, autumn, spring and winter) is about 55,000 km^2 (40% of the region territory) with reindeer live-stock 80-90 thousand for the beginning of the year.

In the first year of realisation of the project RCMA digitised existing statistical information and prepared digital maps of distribution of sown areas in the area of administrative districts of Murmansk county, reindeer pastures areas and main ways of reindeer migration.

Maps are prepared in Map Info format. Scale of topographic base of these maps is 1:500,000.

In this report maps of sown areas and areas of reindeer pastures , see Appendix I, are presented in scale 1:3,000,000. Both maps are transmitted in formats Word 97 for printing of paper copies.

Appendix

Appendix 1.

List of digital maps prepared by RCMA at the first year of AVAIL project.

1. Topographic map contains following layers:
   - coastline of the sea, land, adjacent part of the sea, geographical names;
   - terrestrial water objects;
   - swamps;
   - some elements of the landscape;
   - areas of woods and bushes;
   - settlements.
2. Total ^{137}Cs (mainly nuclear weapons test, Chernobyl) deposition in the Kola Peninsula area Figure 1*
3. Soil map of Kola Peninsula Figure 2 (6 sheets)*
4. Vegetation map of Kola Peninsula
5. Sown areas by subregions of administrative division of Murmansk County (Figure 3)*
6. Reindeer pastures and main pathways of reindeer driving in Murmansk County (Figure 4)*

[*] The heading marked with * are displayed with maps in the Appendix.

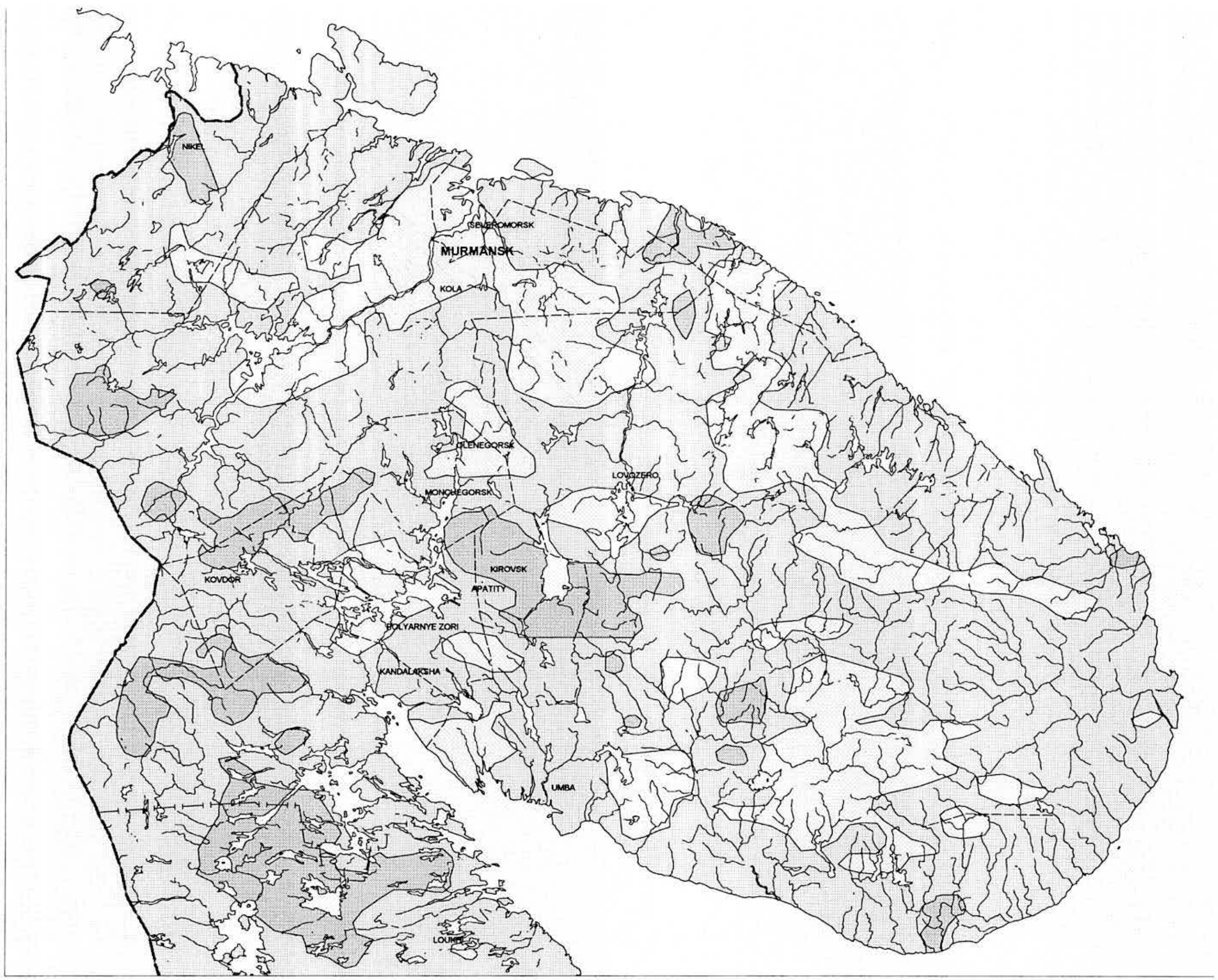


Figure 1. Total caesium–137 (nuclear weapons test, Chernobyl, ...) deposition in the Kola Peninsula area (Scale 1 : 3 000 000)

3. Soil map of Kola peninsula

Below there are listed types and complexes of soils underlined on the map.

1. Well or poorly drained non-gleyic soils

This soils are developed under the condition of dissected mountain and plain watershed on coarse-textured products of weathering of crystalline rocks and sandy unstratified sediments. The group consists of podburs and podzolic Al-Fe-humus soils.

1.1. Podburs (PB).

Podburs are the soils of tundra and northern taiga with an ungleyified and morphologically unpodzolized brown profile A_o-B_{hf}-C (synonyms: cryptopodzolic, tundra illuvial humus, cryogenic taiga ferruginous, Arctic brown, subarctic brown forest soils, etc.). The podburs are formed by the combination of the following processes: leaching, desilification, and relative accumulation of Al and Fe, transformation of layer silicates, illuvial Al-Fe-humus (morphologically unexpressed) podzolization, translocation of clay-silt suspensions. The podburs lack the podzol horizon and the A_o horizon is immediately underlain by the mineral, fersialitized illuvial Al-Fe-humus horizon B. The absence of the podzolic horizon is not related to the of some new process for the podzolic one but can be explained by (a) an extreme weakening, (b) local or temporary slowing down or (c) lithogenic inexpressiveness of podzolization.

1.1.1. Gravely and pebbly tundra podburs (PBt).

1.1.2. Primitive gravely ridge tundra podburs (PBpt).

1.1.3. Above-permafrost gleyic podburs (PBg).

1.1.4. Podzolic podburs (PBp).

1.1.5. Complexes of above-permafrost gleyic podburs and peat-humus transitional bog soils(PBc).

1.2. Podzolic Al-Fe-humus soils (PZ).

Podzolic Al-Fe-humus soils are formed by the same combination of processes as podburs but they are characterized by a greater intensity and (or) duration of the Al-Fe-humus podzolization as compared with podburs, which accounts for the formation or not only an illuvial brown, but a bleached podzolic horizon as well. Podzolic Al-Fe-humus soils differ sharply from the soils with bleached horizon developed on loam and clay by the following characteristic features: (a) the most intensive weathering in the A_2 horizon resulting in accumulation of clay minerals especially of smectite group in the horizon; (b) relative enrichment of solum in iron and aluminium, on the background of which an illuvial-humus redistribution of the amorphous compounds of Al and Fe within the profile takes place.

1.2.1. Podzolic Al-Fe-humus (above-permafrost) gleyic soils **(PZg)**.

1.2.2. Podzolic Al-Fe-humus, illuviall humus-(ferrallitic) **(PZih)**.

1.2.3. Podzolic Al-Fe-humus, reduced illuviall humus **(PZrh)**.

1.2.4. Complexes of podzolic Al-Fe-humus, humus rich, gleyic (peat), and peat-humus transitional bog soils **(PZg)**.

1.2.5. Complexes of podzolic Al-Fe-humus, illuviall humus-(ferrallitic), tundra-bog, peat-gleyic, illuvial humus and bog-tundra dry-peat-gleyic illuvial-humus soils **(PZcx)**.

2. Gley soils with poor internal drainage (G).

This group of soils develops on slightly dissected plains (sometimes in mountains) watersheds of heavy-textured material or sandy-loamy stratified deposits. The group includes homogeneous and differentiated gley soils. The homogeneous gleyic soils are characterized by mineral gleyic profile without any redistribution of clay, SiO_2, Al_2O_3, Fe_2O_3, developed in tundra and northern taiga. Their profile is formed by the combination of the following processes: (a) gleyization and the seasonal oxidation, (b) cryoturbation, (c) transformation of silicates and amorphous compounds in situ, and (d) above-permafrost accumulation of mobile compounds. The differentiated gleyic soils include a great group of soils of tundra and northern taiga with a well expressed eluvial, usually bleached, mineral horizon, low in clay, Al_2O_3, Fe_2O_3. Besides the above mentioned processes (gleyization, cryoturbation, etc.), these soils are characterised by an eluvial-gleyic transfer of iron and, possibly, aluminium, as well as translocation of minerals in suspensions down the profile.

2.1. Tundra near-surface gleyic, differentiated on loam and clay deposits **(TGsgt)**.

2.2. Complex of tundra near-surface gleyic, differentiated and tundra near-surface gleyic, differentiated, dry-peat (sometimes with tundra near-surface gleyic, permafrost soils of spots of bare ground) **(TGsg)**.

2.3. Complex of tundra near-surface gleyic, podzolic and tundra near-surface gleyic, podzolic dry-peat permafrost soils **(TGsgp)**.

2.4 Complex of tundra near-surface gleyic, podzolic, tundra near-surface gleyic, podzolic dry-peat permafrost, and tundra peat-residual, permafrost and raised-bog, permafrost soils **(TGsgbr)**.

The large group of organic bog and tundra-bog soils is characterized by intense peat accumulation under permanent or regular wet (hydromorphic), anaerobic condition, resulting in slow decomposition of organic material, accompanied by processes of cryoturbation6 gleyization and the seasonal oxidation.

3. Organogenous soils with poor internal drainage **(BP)**.

3.1. Complex of tundra peat-residual, permafrost and raised-bog, permafrost soils **(BPt)**.

4. Organic-accumulative, permanently hydromorphic soils **(BS)**.

4.1. Raised peat-bog and peat-gleyic soils **(BSr)**.

4.2. Fen peat and transitional bog soils **(BSl)**.

4.2.1. Fen peat-humus-gleyic bog soils **(BSlg)**.

4.2.2. Peat-humus transitional bog soils **(BSlt)**.

4.2.3. Complex of tundra-bog, peat-gleyic, illuvial humus and bog-tundra dry-peat-gleyic illuvial-humus soils **(BSlih)**.

5. Transitional-accumulative temporary hydromorphic soils

This group includes soils of river flood plain with intense fine grain material accumulation and rendzina formation. The second group consists of various soils of the seashore soil forming processes under maritime condition of fine material accumulation and salinization.

5.1. Alluvial rendzina and alluvial gleyic rendzina **(RA)**.

5.2. Complexes of primitive, stratified, alluvial marsh; primitive marsh soils and marsh rendzina **(M)**.

6. Soils of human impact and agricultural activities **(R)**.

Soil forming bedrock

g(ravel) – Gravel and pebble on crystalline bedrock

m(orain – Loamy sand and sand on moraine deposits

c(lay) – Loamy sand and clay on loamy sand moraine and marine clay

s(chist) – Soils on eluvium of schist

Figure 2. Soil map of Kola Peninsula (Scale 1:1 000 000)
Sheet 1 (6 sheets)

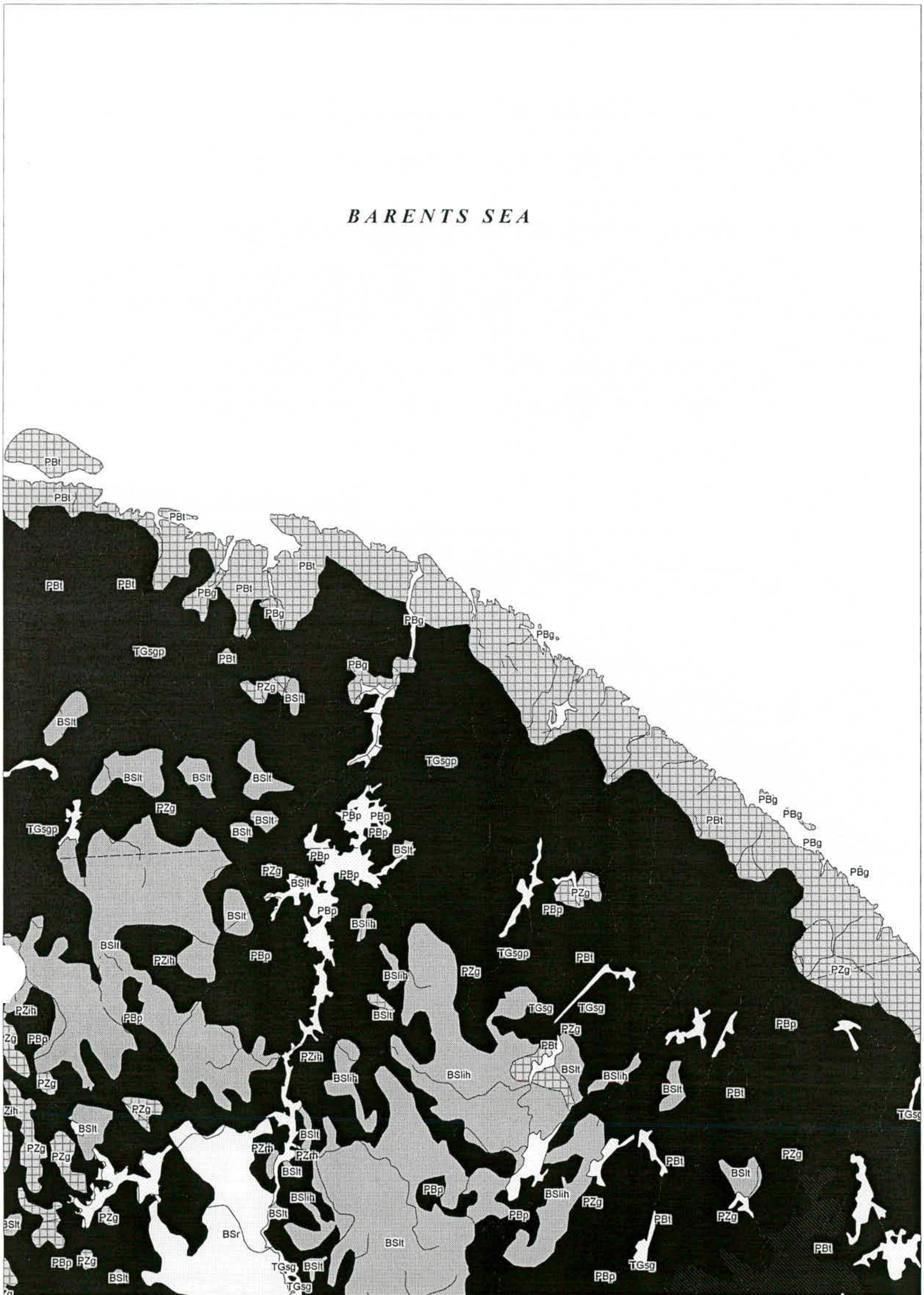


Figure 2. Soil map of Kola Peninsula (Scale 1:1 000 000)
Sheet 2 (6 sheets)

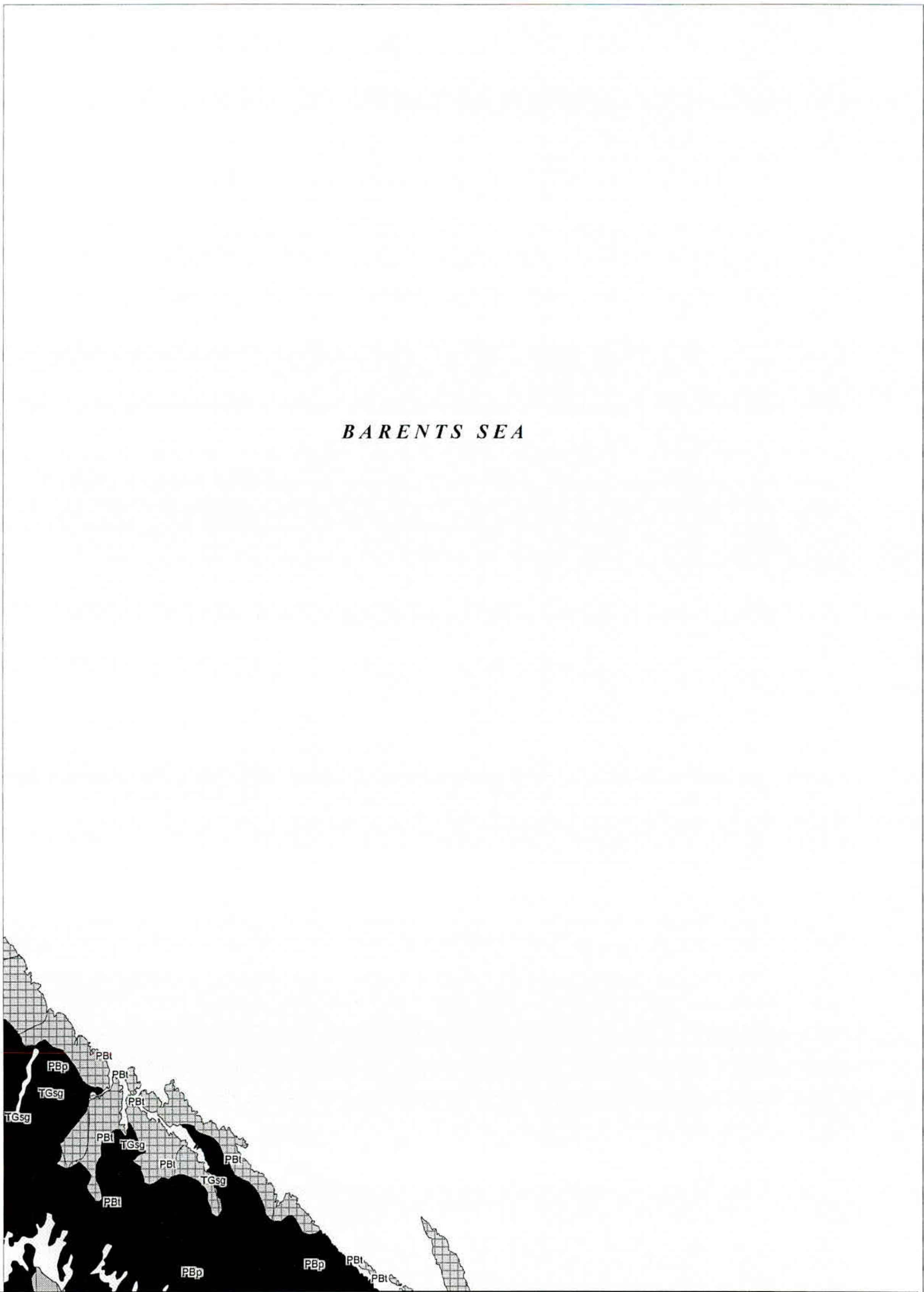


Figure 2. Soil map of Kola Peninsula (Scale 1:1 000 000)
Sheet 3 (6 sheets)

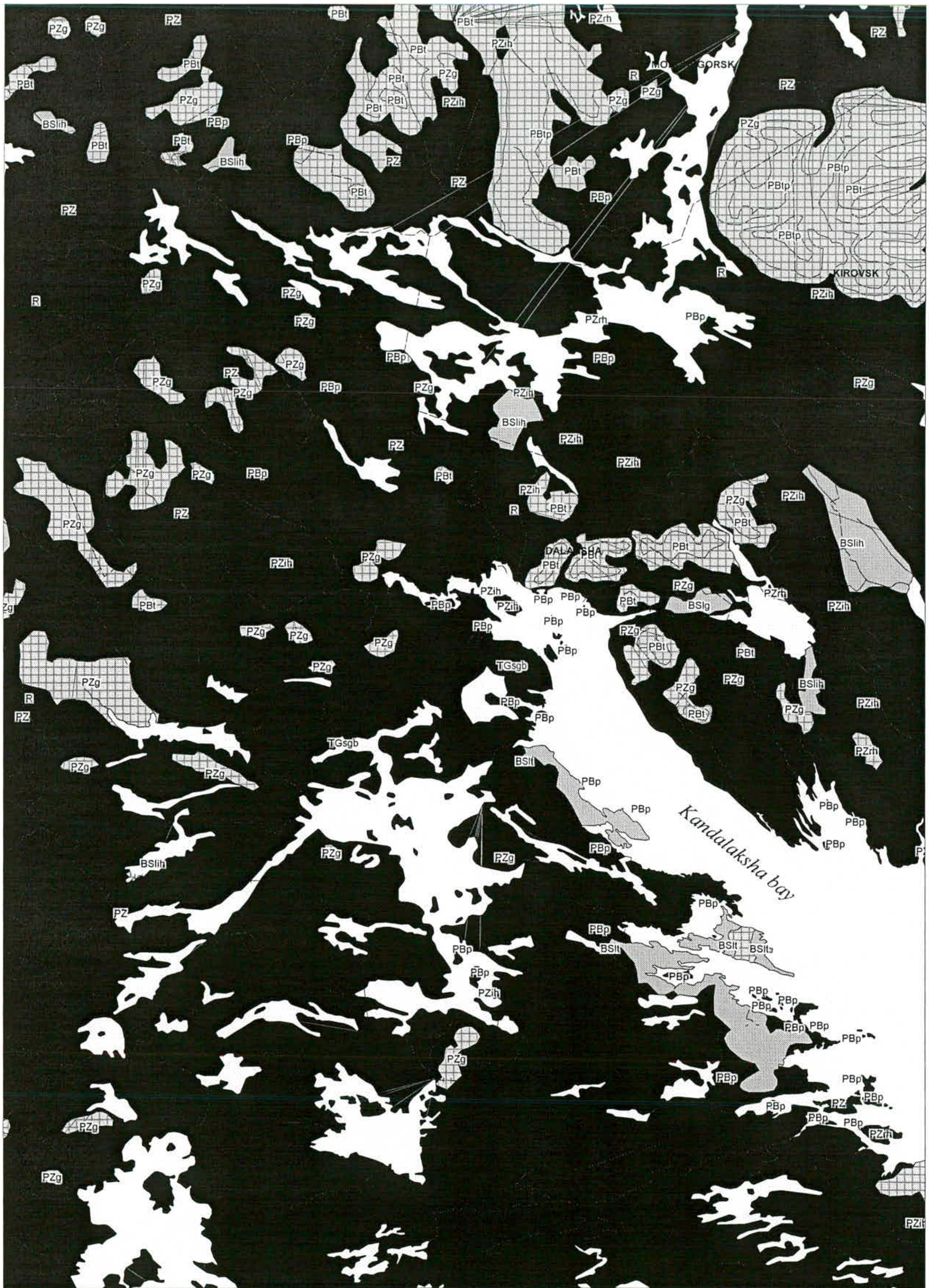


Figure 2. Soil map of Kola Peninsula (Scale 1:1 000 000)
Sheet 4 (6 sheets)

Figure 2. Soil map of Kola Peninsula (Scale 1:1 000 000)
Sheet 5 (6 sheets)

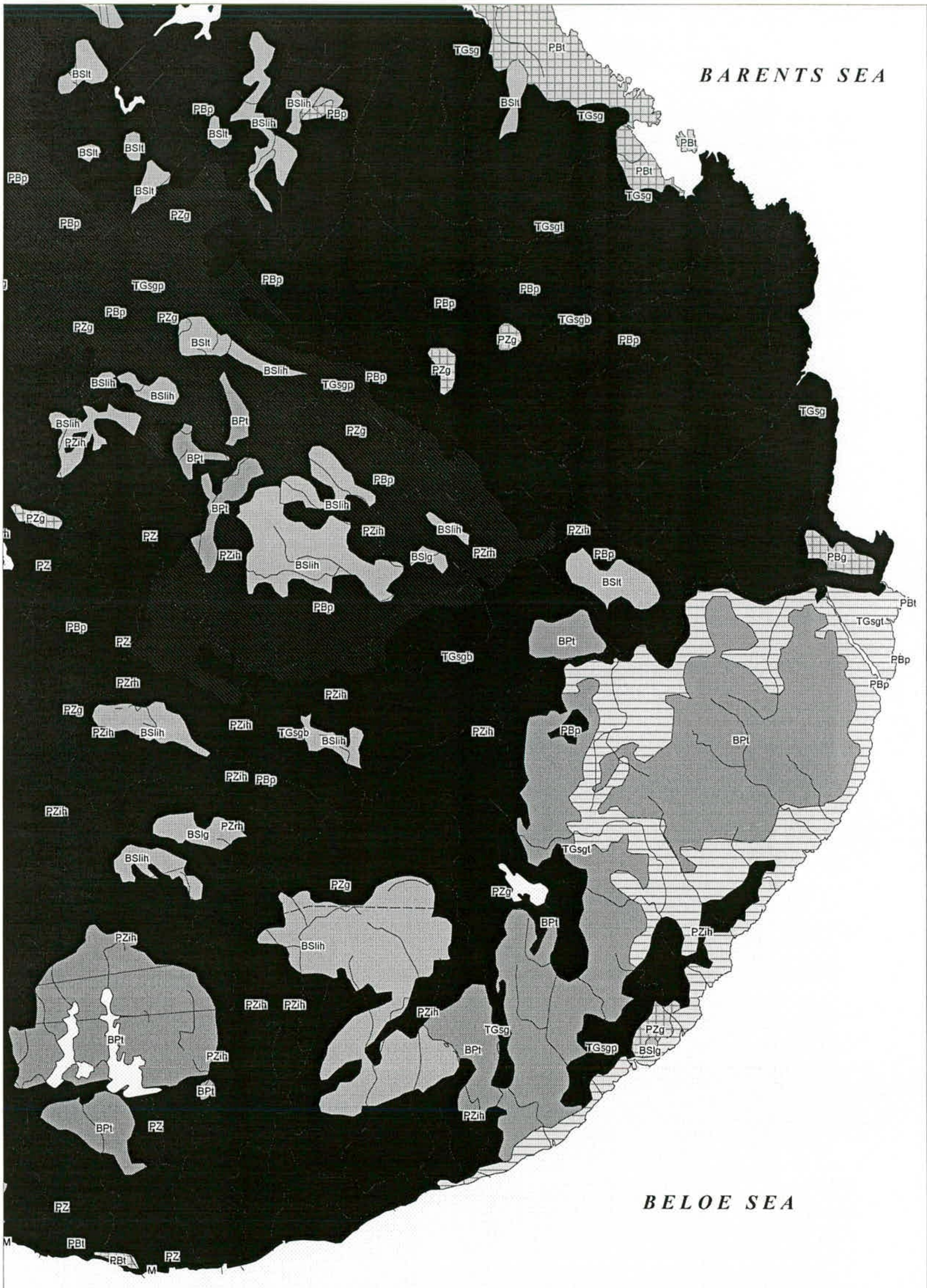


Figure 2. Soil map of Kola Peninsula (Scale 1:1 000 000)
Sheet 6 (6 sheets)

Legend to the soil map of Kola Peninsula

1 **Well or poorly drained non-gleyic soils**

1.1. **PB Podburs**

1.1.1.**PBt** Gravely and pebbly tundra podburs
1.1.2.**PBpt** Primitive gravely ridge tundra podburs
1.1.3.**PBg** Above-permafrost gleyic podburs
1.1.4.**PBp** Podzolic podburs
1.1.5.**PBc** Complexes of above-permafrost gleyic podburs and peat-humus transitional bog soils

1.2. **PZ Podzolic Al-Fe-humus soils**

1.2.1.**PZg** Podzolic Al-Fe-humus (above-permafrost) gleyic soils
1.2.2.**PZih** Podzolic Al-Fe-humus, illuviall humus-(ferrallitic)
1.2.3.**PZrh** Podzolic Al-Fe-humus, reduced illuviall humus
1.2.4.**PZg** Complexes of podzolic Al-Fe-humus, humus rich, gleyic (peat), and peat-humus transitional bog soils
1.2.5.**PZcx** Complexes of podzolic Al-Fe-humus, illuviall humus-(ferrallitic), tundra-bog, peat-gleyic, illuvial humus and bog-tundra dry-peat-gleyic illuvial-humus soils

2.TG Gley soils with poor internal drainage

2.1. **TGsgt** Tundra near-surface gleyic, differentiated on loam and clay deposits
2.2. **TGsg** Complex of tundra near-surface gleyic, differentiated and tundra near-surface gleyic, differentiated, dry-peat (sometimes with tundra near-surface gleyic, permafrost soils of spots of bare ground)
2.3. **TGsgp** Complex of tundra near-surface gleyic, podzolic and tundra near-surface gleyic, podzolic dry-peat permafrost soils
2.4. **TGsgb** Complex of tundra near-surface gleyic, podzolic, tundra near-surface gleyic, podzolic dry-peat permafrost, and tundra peat-residual, permafrost and raised-bog, permafrost soils

3. BP Organogenous soils with poor internal drainage

3.1. **BPt** Complex of tundra peat-residual, permafrost and raised-bog, permafrost soils

4. BS Organic-accumulative, permanently hydromorphic soils

4.1. **BSr** Raised peat-bog and peat-gleyic soils
4.2. **BSl** Fen peat and transitional bog soils
4.2.1. **BSlg** Fen peat-humus-gleyic bog soils
4.2.2. **BSlt** Peat-humus transitional bog soils
4.2.3. **BSlih** Complex of tundra-bog, peat-gleyic, illuvial humus and bog-tundra dry-peat-gleyic illuvial-humus soils

5. Transitional-accumulative temporary hydromorphic soils

5.1. **RA** Alluvial rendzina and alluvial gleyic rendzina
5.2. **M** Complexes of primitive, stratified, alluvial marsh; primitive marsh soils and marsh rendzina

6. R Soils of human impact and agricultural activities

Soil forming bedrock

Gravel and pebble on crystalline bedrock
Loamy sand and sand on moraine deposits
Loamy sand and clay on loamy sand moraine and marine clay
Soils on eluvium of schist

4. Vegetation map of Kola Peninsula

Below there are listed types and complexes of vegetation cover underlined on the digitised map, (not displayed).

1. Tundra **(T)**.
1.1. Ridge tundra **(Tr)**.
(Boulders, outcrops and residual-mountains with patchy vegetation of lichens (*Rhizocarpon, Lecanora, Lecidea, Umbillicaria, Lecanora, etc.*), mosses (*Rhacomirium lanuginosum*) and sparse tufted vascular plants *Cardamine bellidifolia, Novosiversia glacialis, Ranunculus pygmaeus, Dryopteris fragrans*, etc.).

1.2. Southern shrub tundra **(TS)**.
1.2.1. Dwarf shrub birch tundra.
1.2.1.1. Dwarfshrub birch tundra **(TSdsb)** with the sparse layer of *Betula nana*, predominated by hypoarctic dwarfshrubs (*Empetrum hermaphroditum, Vaccinum vitis-idaea* var. *minus*), with constantly presented atlantic plants (*Carex bigelowii, Chamaepericlimenum suecicum, Juncus trifidus*) and lichens (*Cladina mitis, C. alpestris, Cetraria nivalis*) (psammophitic variant).

1.2.1.2. Dwarfshrub-lichen tundra **(TSds)** (*Cetraria islandica, C. nivalis, Cladina mitis, C. alpestris*) with predominance of hypoarctic and Arctic-alpine species (*Empetrum hermaphroditum, Vaccinum vitis-idaea* var. *minus, Arctous alpina, Dryas octopetala, Loiseleuria procumbens*), with constantly presented atlantic plants (*Carex bigelowii, Chamaepericlimenum suecicum, Juncus trifidus*):

1.2.1.2.1. *Empetrum hermaphroditum*-dominated plain variant (petrophitic variant) **(TSdsP)**.

1.2.1.2.2. *Dryas octopetala* and *Empetrum hermaphroditum* –dominated ridge variant **(TSdsR).**

1.2.1.3. Complexes of dwarfshrub birch-lichen tundra and transitional dwarfshrub-herb-bog moss bog (TSdsbBSt).

1.2.2. Shrub birch (Betula nana) **tundra.**

1.2.2.1. Herb-shrub tundra **(TSsbm)** with the dense shrub layer of *Betula nana*, predominated by hypoarctic and boreal species (*Empetrum hermaphroditum, Vaccinium myrtillus, Equisetum pratense*), with constantly presented atlantic plants (*Carex bigelowii, Chamaepericlimenum suecicum*), with **mosses rich** ground layer (*Pleurozium schreberi, Hylocomium splendens, Dicranum elongatum*).

1.2.2.2. Dwarfshrub-shrub tundra **(TSsbs)** with the dense shrub layer of *Betula nana*, predominated by hypoarctic and boreal species (*Empetrum hermaphroditum, Vaccinum vitis-idaea*), with atlantic plants (*Calunna vulgaris, Carex bigelowii*):
1.2.2.2.1. Lichen rich (*Cladina alpestris, C. rangiferina, C. sylvatica, Cetraria islandica*) **of plain** (psammophitic variant) **(TSsbsP)**.

1.2.2.2.2. Prostrate shrub dominated, mountain, with abundance of Arctic-alpine species (*Arctous alpina, Dryas octopetala*) **(TSsbsR)**.

1.2.2.3. Complexes of herb-shrub-mosses tundra and raised bog **(TSsbmBSr).**

1.2.2.4. Complexes of dwarfshrub-shrub, *Betula nana* domiated tundra and transitional dwarfshrub-herb-bog moss bog **(TSsbBSt)**.

1.2.3. Willow shrub tundra **(TSw)**. Willow shrub tundra (*Salix phylicipholia, S. lanata, S. hastata, S. lapponum, S. glauca*) with *Betula nana*, with herbs and dwarfshrubs, predominated by hypoarctic (*Empetrum hermaphroditum, Vaccinum vitis-idaea* var. *minus, V. uliginosum* ssp. *microphyllum*) and boreal (*Vaccinium myrtillus, Trientalis europaea, Solidago virgaurea, Lycopodium clavatum* ssp. *monostachyon*) speciess, rich in mosses (*Polytrichum strictum, P. juniperinum, Pleurozium schreberi, Hylocomium splendens*).

2. Open birch woodland **(BR)**
Birch (*Betula tortuosa*) woodland with admixture of spruce (*Picea obovata s.l.*) and pine (*Pinus sylvestris*), with patchy shrub layer of *Betula nana*, and sparse layer of hypoarctic and boreal dwarfshrubs and herbs (*Vaccinium myrtillus, V. vitis-idaea* var. *minus, V. uliginosum* ssp. *microphyllum, Empetrum hermaphroditum, Gymnocarpium dryopteris, Deschampsia flexuosa, Orthilia secunda, Dryopteris carthusiana*), with constantly presented atlantic plants (*Chamaepericlimenum suecicum, Calunna vulgaris*):

2.1. Herb-dwarfshrub-moss, plain **(BRdsP)** (*Pleurozium schreberi, Hylocomium splendens*).

2.2. Low herb-dwarfshrub, mountain **(BRdsM)** with *Sorbus gorodkovii* and *Juniperus communis*

2.3. Dwarfshrub-lichen, plain **(BRlP)** (Cladina alpestris, C. rangiferina, C. sylvatica, Cetraria islandica)
2.4. Lichen, mountain **(BRlM)** (*Cladina alpestris, C. rangiferina, C. sylvatica, Cetraria islandica*)

2.5. Complexes of mountain lichen open birch woodland and dwarfshrub-lichen tundra **(BRdsTSds).**

2.6. Complexes of mountain lichen open birch woodland and lichen-shrub birch *(Betula nana)* tundra **(BRdsTSsb).**

2.7. Complexes of herb-dwarfshrub-moss-birch open woodland and transitional dwarfshrub-herb-bog moss bog **(BRdsBSt).**

3. Spruce forest **(S)**

3.1. Pre-tundra spruce forest (spruce open woodland) **(OS)**

3.1.1. Birch-spruce (Picea obovata, Betula tortuosa) open woodland **(OS)** with patchy willow-birch shrub layer (Betula nana, Salix lapponum, S. lanata, S. phylicipholia), and pattern of mosses (Sphagnum girgensohnii, Polytrichum commune), sedges and dwarfshrubs in ground layer (Ledum palustre, Vaccinium uliginosum, Carex globularis) (hydrophytic variant).

3.1.2. Complexes of birch-spruce open woodland and raised bog **(OSBSr).**

3.1.3. Complexes of birch-spruce open woodland and dwarfshrub-shrub tundra **(OSTSsb).**

3.2. Northern taiga **(SP)** (northern coniferous forest).

3.2.1. Spruce with admixture of pine and birch **(SP)** (*Picea obovata, P. abies, Pinus sylvestris, Betula pubescens, B. tortuosa*) forest, usually open, with birch (*Betula nana)* in shrub layer, and pattern of lichens and mosses in ground layer(*Pleurozium schreberi, Hylocomium splendens, Polytrichum commune, Sphagnum girgensohnii, S. nemoreum, Cladina sylvatica, C. rangiferina*), predominated by hypoarctic and boreal dwarfshrubs (*Vaccinium uliginosum, V. myrtillus, V. vitis-idaea, Empetrum hermaphroditum, Ledum palustre*).

3.2.2. Complexes of spruce with admixture of pine and birch forest, birch-spruce open woodland, pine-dwarfshrub-bog moss meso-oligotrophic bog and «aapa»-bog **(SPBa).**

4. Northern pine forest (P).

4.1. Pine (P) (Pinus sylvestris) lichen and moss-lichen (Cladina alpestris, C. sylvatica, C. rangiferina, Cetraria islandica, Pleurozium schreberi) dwarfshrub (Empetrum hermaphroditum, Vaccinium **vitis-idaea**) open forest, partly secondary inhabiting sites of spruce forest (Empetrum-lichen, Empetrum–Vaccinium vitis-idaea-lichen and Empetrum - Vaccinium vitis-idaea -mosses).
4.2. Complexes of pine, spruce-pine moss-lichen open forests, bog mosses-pine open forest, birch-spruce open woodland, pine-dwarfshrub-bog moss meso-oligotrophic bog and «aapa»-bog **(PSPBa).**

4.3. Complexes of pine, spruce-pine moss-lichen open forests and herb-dwarfshrub-moss-birch open woodland of plain **(PSPBRds).**

5. Bog vegetation **(B)**.
5.1. Spagnum-dominated bog vegetation **(BS)**.
5.1.1. Pine-cottongrass tussock-dwarfshrub-bog moss raised bog **(BSr)** (*Pinus sylvestris, Eriophorum vaginatum, Chamaedaphne calyculata, Calluna vulgaris, Vaccinium uliginosum, Rubus chamaemorus, Sphagnum angustifolium, S. fuscum, S. nemoreum*).

5.1.2. Dwarfshrub-herb-bog moss and herb-bog moss, meso-oligotrophic to mesotrophic, transitional **(BSt):**

5.1.2.1. **(BStH)** hypoarctic with *Carex aquatilis* s.l., *C. rariflora, C. rotundata, C. chordorrhiza, Eriophorum russeolum, Sphagnum fallax, S. lindbergii, S. majus, S. obtusum*

5.1.2.2. **(BStB)** boreal with *Oxycoccus palustris, Carex lasiocarpa, C. rostrata, Baeothryon caespitosum, Scheuchzeria palustris, Sphagnum fallax, S. obtusum, S. papillosum*, predominated by *Betula nana*

5.2. Herb-lichen-moss bog **(Bf)**.
Birch shrub (*Betula nana*) herb-dwarfshrub-moss-lichen (*Ledum palustre, Vaccinium uliginosum, V. vitis-idaea, Rubus chamaemorus, Dicranum elongatum, D. congestum, Polytrichum alpestre, Cetraria nivalis*) on mound and cottongrass-sedge-bog moss (*Eriophorum russeolum, Carex rariflora, C. rotundata, Sphagnum balticum*) in depression (ersey) flat mound, of southern tundra.

5.3. Herb-moss bog (aapa) (Ba). Shrub-sedge-lichen-bog moss (*Empetrum hermaphroditum, Baeothryon caespitosum, Cladonia spp., Cladina spp., Sphagnum fuscum*) with *Betula nana* on ridge, bog moss-sedge (*Carex rotundata, C. rariflora, Sphagnum balticum, S. jensenii, S. lindbergii*) and moss-herb (*Eriophorum polystachyon, E. russeoluum, Drepanocladus fluitans*) in hummock, in the meso-oligotrophic-meso-eutrophic hummock-ridge complex in the centre with the bordering dwarfshrub-bog moss meso-oligotrophic vegetation **(aapa).**

5.4. Herb and herb-moss bog **(Bs)** Sedge and sedge-moss (*Carex lasiocarpa, C. limosa, C. diandra, C. rostrata, C. nigra, C. vesicaria, Equisetum fluviatile, Calamagrostis neglecta, Menyanthes trifoliata, Scorpidium scorpioides, Drepanocladus* spp.), usually with bog mosses (*Spagnum contortum, S. subsecundum, S. teres, S. warnstorfii*) meso-eutrophic.

6. Seashore vegetation. Seashore sparse meadows and sedge marshes **(M).**

7. Ruderal vegetation. Ruderal and weed vegetation **(R)** of settlements and its vicinities.

Figure 3. Sown areas by sub-regions of administrative division of Murmansk County

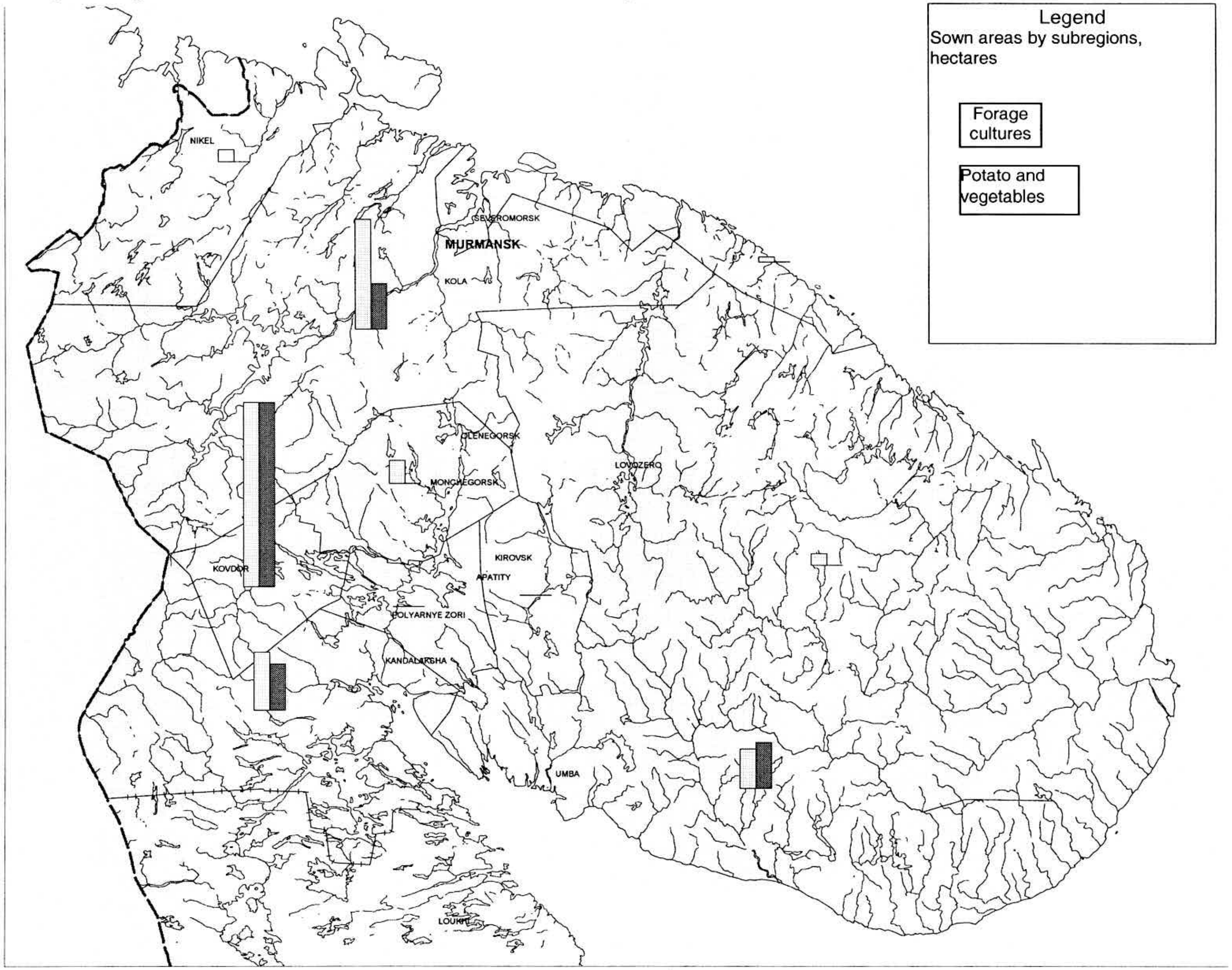
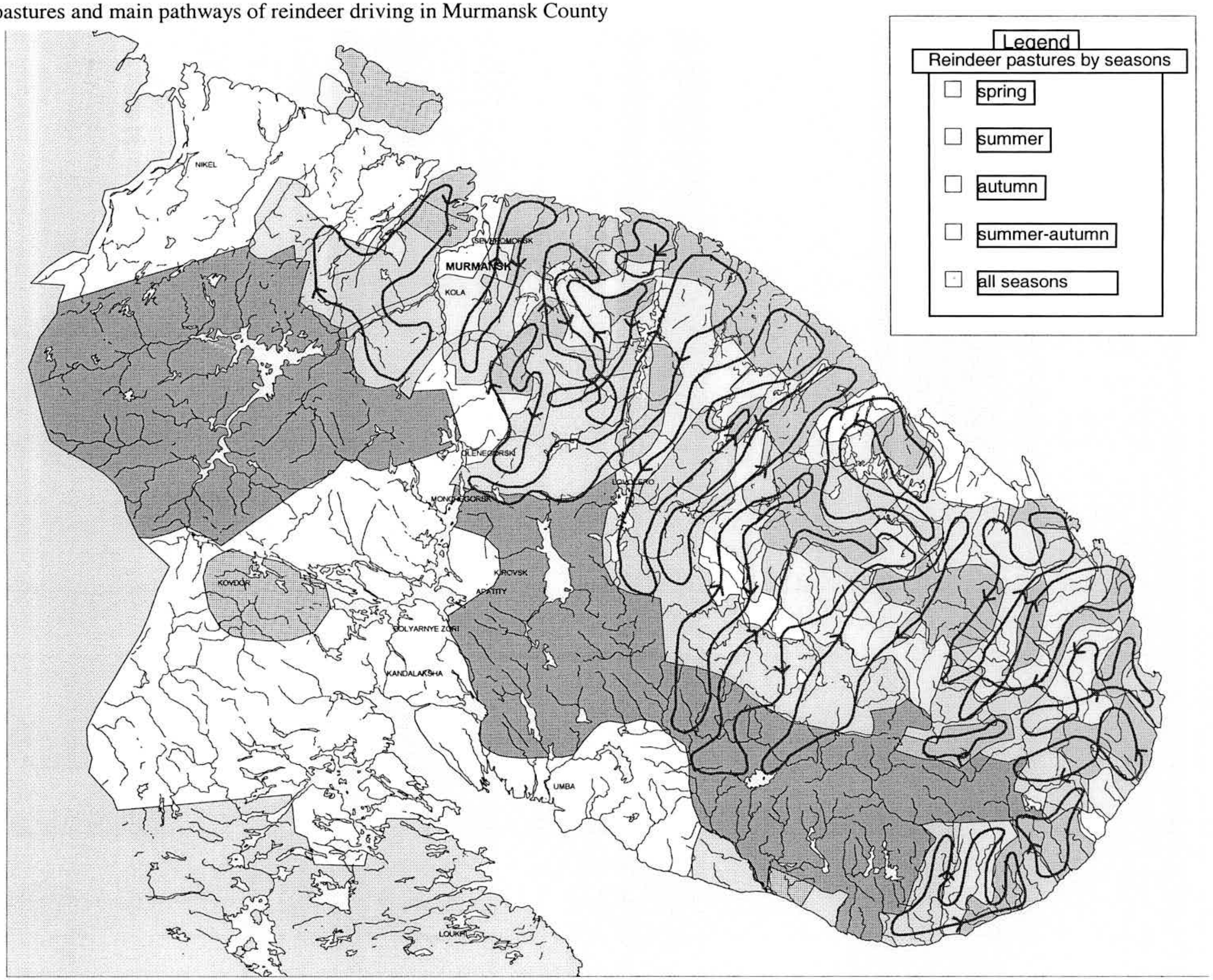


Figure 4. Reindeer pastures and main pathways of reindeer driving in Murmansk County



Appendix 2

Questionnaire for Arctic inhabitants, 1998 and 1999

1. Name, given name, paternity .... 2. Sex: M _ F _

3. Date of birth .... 4. Nationality .... 5. Confession ....

6. Weight (kg): .... 7. Settlement: .... 8. Occupation: ....

9. How many are you in your family? .... children, ... adults ....

10. Ownership of: kitchen-garden _ cow _ poultry _ goat _ sheep _ pig _ reindeer _

11. Results of radiometry of the body:

Date	Device (type, No.)	Time of measurement, s	N, pulses	N_b, pulses	Q, nCi	Comments
....../... 1998						

12. Food ration in 1998/1999 (kg/day):

Meat	Reindeer	Beef	Pork	Mutton	Poultry
Consumption rate					

13. Food ration in 1998/1999 (kg/day):

Source	Milk	Meat	Bread	Potatoes	Vegetables	Fruits	Eggs	Fish
Private farm								
Market								
Shop								

14. Do you consume fish from local lakes and rivers?

No _ Sometimes _ Frequently _ Very frequently _

15. Do you consume mushrooms?

No _ Sometimes _ Frequently _ Very frequently _

16. Do you consume meat of wild animals?

No _ Sometimes _ Frequently _ Very frequently _

17. Meat of what wild animals do you consume?

Appendix 3

Minutes from the AVAIL meeting at the Regional Centre for Monitoring of the Arctic, St. Petersburg, 17-18 December 1998

Participants:

NORWAY
Norwegian Radiation Protection Authority
Strand Per
Mikhail Iosjpe
Justin Brown
Line Diana Blytt

UNITED KINGDOM
Institute of Terrestrial Ecology
Simon Wright

RUSSIA
RTC "Protection"
Balonov M.I.
Bruk G.Ya.
Golikov V.U.
Travnikova I.G.
Shutov V.N.
Logacheva I.
Danilova I.

Roshydromet
Tsaturov Yu.S.

Regional Centre for Monitoring of the Arctic
Melnikov S.A.
Gorshkov A.

The meeting was opened by M.I.Balonov, who told about aims and purposes of the starting AVAIL Project, and next spoke in detail about each of work packages. He underlined that within this Project, we work in the European part of the Arctic. As a study site for 1999-2000, the Arkhangelsk region, including the Nenets autonomous area was chosen.

The project has been divided into 5 work packages.

Work Package 1 : Synthesis and evaluation of currently available information - RCMA
Parameters for radionuclide transfer in the terrestrial Arctic ecosystem, which eventually result in human exposure, will be determined. Information will be synthesised from existing experimental data collected mainly in Russia and in Scandinavian countries both after global radioactive fallout in 1960s-1970s and after the Chernobyl accident in 1986 and during subsequent years.

The data on radioactive contamination of the European Arctic obtained earlier as a result of field investigations and generalised in the European Atlas, and also obtained as a result of simulations within the AMAP Project, must be analysed by the Project participants under RCMA co-ordination during the first half of the 1999 - ***see Action list***.

NRPA and ITE must collect and analyse the available data on transfer/fluxes of radionuclides in the Arctic. Here, important are the data on contamination of fresh-water fish that will be obtained within the other project (bilateral Russian - Norwagian collaboration). Dr. I.Kryshev from "Typhoon", Obninsk, develops the model for a fresh-water ecosystem within the frames of the bilateral project. Shutov, Bruk, and Travnikova will present the data on radioactive contamination of mushrooms on the Kola Peninsula (RTCP, the results of the 1998 summer expedition).

This work package should also involve an assessment of the relevant parameters to external and internal dose, e.g. human behaviour and food consumption for the inhabitants of the northern areas (considered on the scale of individual regions). The data on food rations of local inhabitants will be presented: from Russia - by I.Travnikova, from Norway - by Lavrans Skuterud.

Besides that, RCMA should collect demographic data on the supposed study site not later than September 1999. Also, information about types of dwellings and the mode of behaviour, especially for local population, is necessary. In this connection, V.Golikov will prepare a separate questionnaire for physicians, that work in the region under investigation. This questionnaire, together with the list of parameters necessary for calculation of the external dose in population, must be given to A.Gorshkov in December 1998 - January 1999 - ***see Action list.***

Emphasis will be placed on identifying gaps in knowledge.

Work Package 2 : Fluxes in the Arctic environment - NRPA

Within this Work package existing radioecological data will be analysed to quantify radionuclide fluxes in the Arctic environment. The quantification of fluxes will be achieved through field studies and the use of relevant transfer and production data. This data can be used to parameterize internal dose models. V.Golikov is responsible for simulation on the Russian side in this Project.

- L. Blytt presented the data prepared jointly with Lavrans Skuterud:
- On cesium-137 concentration in inhabitants of the Northern Norway, beginning from 1965;
- On cesium-137 concentration in venison, beginning from 1965;
- On ecological half-life.

V.N.Shutov presented the preliminary results of the expedition that took place in the summer 1998 on the Kola Peninsula. The techniques for separation of soil in layers were discussed. We separate the layers in centimetres, but it is important to separate also in soil horizons (the layer with organic, etc.). The joint opinion was assumed that it is important to perform the analysis in different countries according to the same technique. The decision was made to compare the techniques of sampling before spring, to determine the transfer factors etc. - ***see Action list.***

Discussed was the organisation and the programme of the spring expedition to Lovozero, in which not only Norwegian, but also Finnish and Swedish colleagues will possibly take part.

The field work will involve the sampling of vegetation and soils covering a wide range of ecosystems - ***see Action list.*** Special emphasis will be placed on wild foods (mushrooms, berries and game animals) and those foodstuffs consumed by indigenous peoples (reindeer meat and freshwater fish).

The purposes of the expedition are to make more exact the transfer factors of radionuclides along Arctic ecological food chains: lichen - reindeer - man, from soil to mushrooms and berries, fresh-water lakes and rivers - fish, and to make more exact ecological half-life.

The study sites were approved once more:
The year 1999 - the Arkhangelsk region (the Nenets national area) and Norway (Finnmark);
The year 2000 - the Arkhangelsk region (the Nenets national area).

Work Package 3 : Indigenous peoples - dietary habits and vulnerability - NRPA

I.G.Travnikova presented the preliminary results of the Kola expedition, where 20 reindeer-breeders were measured and polled. The analysis of the obtained results made evident the necessity to remake the questionnaire, because the food rations of the indigenous population radically differ from those of common population. Besides that, the literature data and own obtained information makes evident the necessity of spring expedition to Lovozero, to try to poll and measure the same reindeer-breeders that were polled and measured in August 1998. It is supposed that the cesium-137 content in their body must grow as compared with the previous one, because their winter ration is mainly venison, whose cesium-137 contamination levels are especially high in winter and spring, before reindeers go to open pastures.

The study of demographics, dietary and living habits will be undertaken in the Arkhangelsk region and Finnmark in 1999-2000 during expeditions identified in the WP2. This will involve the use of updated questionnaires during field expeditions and the integration of data collated as part of work package 1. Before spring and summer expeditions questionnairies should be updated and harmonised between Russian and Norwegian groups -***see Action list.*** WBC equipment should be checked and calibrated again - ***see Action list.*** The aim will be to improve dose and risk assessments for both average residents and members of the most exposed indigenous population groups in the northern areas and to provide essential information for the parameterisation of dose and vulnerability models.

Work package 4 : Modelling of internal and external dose - RTCP

The key elements in an Arctic radioecological model should be the incorporation of both relevant northern food chains including the terrestrial lichen-reindeer-man chain, freshwater ecosystems, forest ecosystems with mushrooms and berries, local agricultural ecosystems, marine ecosystems and external dose unit. Parameters of this model can be derived mainly from the results of radiation monitoring programmes performed in the Arctic areas of Russia and Scandinavian countries after the global fallout and the Chernobyl accident. These data have been collated, through extensive international collaboration, in the AMAP data centre at NRPA.

V.Golikov and I.Logacheva presented the structure and the mathematics of the first version of the model for internal exposure of man in the Arctic environment trough the indicated food chains. The possibilities for obtaining the necessary regional information for determination of the corresponding model parameters were discussed. The decision was made to perform a joint work in NRPA in the AMAP Data Centre in spring 1999, and later - according to the necessity - *see Action list.* Besides that, it was decided to form a small working group on making more exact the parameters necessary for creation of the model for internal exposure, in particular, to consider dietary ration and dietary habits in detail.

During the first stage it will be possible to produce deterministic estimates of the most probable radiological consequences (individual and collective doses etc.). At the next stage stochastic modeling and uncertainty analysis would be introduced. This work will be closely linked to work package 5 so that the internal and external dose models may be easily integrated into GIS.

In addition to assessing dose to humans, the model would include quantification of irradiation of some key components of the higher levels of Arctic biota (reindeer, freshwater fish etc.).

The discussions resulted in conclusion that the investigation of biota is not reflected in the working plans, and must be added there - *see Action list.*.

Work Package 5 : Vulnerability and spatial variability

This work package starts from the second year. A preliminary large-scale analysis of the consequences of radioactive contamination of the Arctic (areas above 60^0 N for the 8 Arctic countries) has recently been successfully conducted using GIS-techniques (Geographical Information Systems). GIS will be used to analyse radiological consequences for northern areas because it allows the integration of geographically varying information: transfer rates, population levels and foodstuff production rates in conjunction with new dietary information. This approach will also allow better estimation of the impacts of a future accident and will allow the rapid identification of areas where more detailed research would have to be undertaken or where specific countermeasure strategies need to be applied. The model will be validated using independent sets of experimental data collected in expeditions to Arctic areas. The end result should be a versatile model which can be implemented in the assessment of possible radiological consequences of accidental radioactive contamination in terrestrial areas of the European and Russian Arctic. Emphasis will be placed on the specific vulnerability of these areas.

Simon Wright told about GIS models, about calculation of critical loads for different areas, about maps of the critical load. For these works, the knowledge of soils, vegetation, landuse, reindeer migrations, area contamination and demography is necessary.

In winter 1999, it is necessary to form the list of questions for collecting the necessary information - for example, about the boundaries of areas of agricultural activity in different regions, the reindeer regions etc. - *see Action list.*

Critical load maps will be produced as part of this work package. These critical load maps will represent an integration of all the spatial parameters necessary to calculate the levels in food products. The critical load is then set to an intervention limit, i.e. 370 Bq l^{-1} in cow milk or other levels for specific foodstuff. It is then easy to compare the critical load map with a map of a deposition event, for example a contamination scenario after an accident at Kola NPP, to identify areas where the food product will be contaminated above its intervention limit.

The scenario was discussed, under which the possibility of termination of consumption of local food products was envisaged immediately after the release. It was underlined once more that the information is necessary on soils, landscapes, and vegetation. The decision was made to use for validation only those data that will not be used for creation of the model.

The terms for the annual and deliverables reports were determined.

ACTION LIST for all partners (1999)

RTCP - M. Balonov

No.	Task	Work package	Responsible institutes	Dead line
1	Collation of dietary information	1	RTCP	1 September
2	Collation of habit survey data	1	RTCP	1 September
3	Identification of knowledge gaps	1	RTCP/ NRPA/ITE	1 September
4	Sampling strategy	2	RTCP /NRPA/ITE	1 September
5	Field-work - soils, foodstuffs, WBC, interviews	2	ALL	
6	Sampling strategy - questionnaire preparation	3	NRPA/RTCP	1 September
7	Internal dose parametrisation	4	RTCP/HYD/RCMA /NRPA	next year
8	External dose model application	4	RTCP	next year

HYD/RCMA - S.Melnikov

No.	Task	Work package	Responsible institutes	Dead line
1	Review of radioactive contamination in the Arctic	1	HYD/RCMA	1June
2	Collation of demographic information	1	HYD/RCMA	1 September
3	Collation of data on agricultural landuse and reideer breeding areas for Kola Peninsula	2	RCMA	1 September
4	Soil maps for Kola Peninsula	2	RCMA	1 September
5	Internal dose parametrisation	4	RTCP / HYD/ RCMA /NRPA	next year

NRPA - P. Strand

No.	Task	Work package	Responsible institutes	Dead line
1	Review of transfer/fluxes in the Arctic	1	NRPA/ITE	1 June
2	Identification of knowledge gaps	1	RTCP/NRPA/ITE	1 September
3	Sampling strategy	2	RTCP/NRPA/ITE	1 September
4	Field-work - soils, foodstuffs	2	ALL	
5	Sampling strategy - questionnaire preparation	3	NRPA/RTCP	1 September
6	Internal dose parametrisation	4	RTCP/HYD/RCMA /NRPA	next year

ITE - B.Howard

No.	Task	Work package	Responsible institutes	Dead line
1	Review of transfer/fluxes in the Arctic	1	NRPA/ITE	1 June
2	Identification of knowledge gaps	1	RTCP/NRPA/ITE	1 September
3	Sampling strategy	2	RTCP/NRPA/ITE	1 September
4	Field-work - soils, foodstuffs	2	ALL	

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